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EDITORIAL.

The London Underground Railway.—From an English engineer now traveling in this country, and who was before connected with the construction of this work, we learn several items of interest. Thus the engines employed are not, as is generally supposed, specially arranged for the suppression of smoke, etc.—in other words, of what is here known as the dummy pattern,—but are precisely of the usual form, with the exception of two points. In the first place, they are so arranged that the exhaust may be, at will, turned into the tank, in place of the chimney; and secondly, the furnace may be shut up air-tight at a moment's notice.

The plan of working them is as follows:—The road, we should premise, is not a continuous tunnel, but a series of alternate tunnels and open cuttings. In the open cutting the engines are run as on any other road; but as soon as a tunnel is reached, the exhaust is turned into the tank, the fire-box shut tight, and the engine run through by the accumulated heat in the furnace and boiler. The

cost of this road, it may also be interesting to know, was about $4,000,000 per mile.

Machine Packing.—In selecting the best material for packing, it will be found very useful to bear in mind the following fact:—If the material used is itself impervious, only so much pressure need be applied as will cause it to fit tightly against the adjacent parts; but if the packing itself is porous, then a far greater pressure will be demanded, to bring its particles into close contact, and so render it impervious. This fact, we think, has much to do with the acknowledged superiority of rubber packing in certain cases.

Fatal Explosion of an Oxygen Reservoir.—An accident occurred a short time since, at the Pennsylvania Hospital for the Insane, in West Philadelphia, of which we shall here give a full account, because a knowledge of this is likely to prevent similar disasters in future. In this establishment, the Magic Lantern for more than twenty years, under the direction of Dr Kirkbride, Superintendent of the Institution, has been constantly employed, and has proved itself of incalculable service in connection with the neutral treatment pursued, affording as it does an inexhaustible supply of amusement, instruction, and mental occupation, without excitement. Long before the stereopticon was known to the public at large, lanterns for dissolving views and photographic projections, were familiar in that locality. Every improvement in the lanterns and their illumination, was promptly introduced, and for more than twelve years oxygen has been constantly made, and every night consumed, without accident or injury, until November 14th, when, during the manufacture of a fresh supply, the oxygen reservoir exploded, and a thick board used to support the weights placed upon it, striking the man employed in making the gas (who was close to it) on the forehead, fractured his skull. At the request of Dr. Kirkbride, we examined the apparatus, and think that the history of this accident may be briefly stated as follows:—The oxygen was made from chlorate of potash, without oxide of manganese, in a grinding machine, such as is figured and described in this Journal, vol. liii., page 58, the retort or pot, was heated in one of the ranges of the kitchen, on the ground-floor, the outlet pipe was connected, by a thick rubber hose (three-ply), with an iron tube passing through the floor, and leading into a tin gas-holder of the usual construction, in the cellar below. In this particular instance, the residue from a previous operation was, through carelessness or inadvertence, left in the retort, occupying

probably about three-quarters of its capacity. When the retort was supposed to be hot enough, about a pound and a quarter of chlorate of potash was slowly ground in, but as there was no wash-bottle or other means of indication, the operator could not tell whether any of it was decomposed before the whole was introduced, and we think it extremely probable, that, owing to the residue in the retort, the whole charge was introduced before any gas had been liberated; in fact, when we examined the contents of the retort, we found a notable quantity of chlorate still remaining. Under these conditions, as all are aware, a large amount of chlorate would fuse, and then begin to liberate oxygen with violence, and it would be highly probable that sparks from dust or chips would be carried as far as the rubber tube, and ignited. We have, indeed, in our own experience, on three occasions, observed this very thing to happen when making oxygen from the materials placed in bulk in a retort. In those cases, however, the tube being thin, was instantly melted through; but in the present instance, the tube being very thick, and having an interlining of cloth, would resist for some time, and allow the white-hot flame of India rubber burning in oxygen to distill the interior rubber lining from the remainder of the tube, and drive it forward as inflammable gas into the reservoir. While this was going on, the man in charge of the process was on his way, by a somewhat circuitous staircase and passages, to the cellar below, to see how the reservoir stood; finding it less high than he expected, he probably lifted it, thinking it had stuck fast, and this relief of pressure caused the flow of gas to be more rapid, and thus carry fire into the reservoir, now containing the explosive mixture. The gas nowhere passed through water on its route. The rubber tube was found to be completely stripped of its interior lining, and burnt quite through at one point near the retort, which remained undisturbed on the fire, from which it was removed, by Dr. Jones, Assistant Medical Director, a short time after the explosion. The ultimate cause of this accident, we consider the absence of a wash-bottle in sight of the person managing the retort. With this adjunct, the grinding apparatus, in the hands of one possessing the most moderate intelligence, is absolutely safe, but without it, no process we have heard of is, with pure materials, more dangerous. With a wash-bottle in sight, a violent action resulting from an accumulation of material is impossible; for if each charge admitted is not at once decomposed, we are notified of the fact. Thus all risk of igniting the rubber tube

is avoided, or, if it should occur, the smoke would at once show in the wash-bottle. The rubber tube might also be replaced by one of lead, but here a more serious danger is incurred in case of stoppage.

The Camphor Storm Glass.—Professor C. Tomlinson, Kings College, W. C., in a late letter to the editor of the *Chemical News*, alluded to a paper published by himself in the *Philosophical Magazine* for August, 1863, in which he proved, that the instrument above named owed its crystalline changes not to variations in moisture, barometric pressure, light, or electricity, but simply to those of heat, and adds certain new points, among which is this. By dipping a piece of filter paper in ether, and placing it on one of those glasses, a crystalline deposit may be determined to any part at pleasure, in a few seconds, and will conform to any pattern or device we may give the paper.

Time of the Earth's rotation effected by the accumulation of Meteoric Matter.—In a lecture delivered before the British Association at Dundee, Professor Alexander Herschel makes the following curious observation:—A question which at present agitates the minds of physical astronomers, is to ascertain whether a slight acceleration of the moon's apparent motion can be attributed to an error in calculation, or whether the earth in the course of ages has lost in its speed of rotation. The lunar tables, which exactly represent the moon's apparent motion at the present time, do not absolutely give the hour of an eclipse which happened when the sun was setting at Babylon, some hundred years B. C. The eclipse began, according to the table, when the sun was already below the horizon, and it would be invisible at Babylon. But if the earth's rotation had been a little more rapid in former times than at present, the sun, instead of having set, would have appeared eclipsed before his setting, as was indeed the fact. To account for this change in motion, the friction of the tides has been considered, a slow accumulation of meteorites upon the earth's surface would undoubtedly diminish its speed of rotation. The change of a hundredth part of a second in the length of the day, since the earliest observations, would explain the existing discrepancy.

The Electric Spark—Space-penetrating power of its light.—It was long since shown that the Leyden jar discharge produced a light of higher intensity even than that from the sun, though of course of enormously less volume. It would now appear that this intensity involves an equal power of penetrating space. In

a late letter to the *Chemical News*, the Abbé Moigno tells us, that M. Felix Lucas has shown, that a spark yielding an actual light but $\frac{1}{2000}$th of a carcel wick (measured by the photometer employed by the Lighthouse Administration), showed a marked superiority over an electric (voltaic) light, equal to one hundred and twenty-five carcel lamps.

Means of increasing the quantity of Electricity from Induction Coils.—In the proceedings of the Royal Society, vol. xv., No. 84, just received, we find an admirable article by the Rev. T. R. Robinson, D.D., on the above subject. In this, the author first points out the value of an increase in the quantity of electricity developed by these machines, and then proceeds to discuss the various means by which this increase may be secured.

First. Increased power of the exciting battery; this, however, is open to two objections: injury to the acting surface of the contact breaker, and disproportionate minuteness of effect, beyond moderate limits, thus in certain experiments, 1000 of a unit repressing the product of the current, and number of spires, gave a result of 576 in one magnet, and 235 in another; another 1000 units adds to these effects 87 and 19, respectively; a third 1000 adds 35 and 8, and a fourth 1000 only 19 and 3.

Secondly. The outer helix may be made of longer or of thicker wire; here, however, we find that length gives no increase in quantity, while that obtained by thickness soon reaches a limit. We therefore come to the third and last method, by combining several coils collaterally, in a manner analogous to that in which galvanic cells are united for quantity.

The apparatus employed to produce and test these effects, was briefly, as follows: On an oaken table were fixed, vertically, four primary helices, their axes being 12 and 18 inches apart; two of these are 12½ inches high, having in four layers 383 and 343 spires, respectively; the other two are 13½ inches high, and have each, in two layers, 181 spires. The current normally is passed first through one of the last mentioned coils of 181 spires, is then divided between the first pair of 383–343 spires, and is finally passed through the remaining coil of 181 spires. Thus the exciting force (equal current × by number of spires) is about equal in each coil. A Fizeau's condenser is placed on a shelf below; though this is so important in producing sparks, it has very little effect on quantity, this being with it 1·000, without it 0·9948. This of course is with a continual circuit. These primaries are all thoroughly insulated with glass jars.

On these were supported, in various combinations, eight secondary helices of different length and thickness of wire.

Without entering into the detail of experiments, we will simply state the general result. First. Two helices in series give no increase of quantity, though their intensity nearly equals the sum. Second. The quantity of helices connected collaterally, equals the sum of their separate effects. Third. The quantity increases with the diameter of the wire, to a maximum reached when this is about $\frac{1}{6}$'$_5$th of an inch. Fourth. Helices on different primaries combined, produce more effect than when on the same primary.

In combining various instruments, their helices may be extremely unequal without loss of effect; these primaries should not be consecutively connected if numerous, as the action of the current would then be very destructive to the circuit breaker. It would indeed be best to have separate batteries for each instrument, all the circuits being broken (as it is easy to arrange) by the same rheotome.

Induction coils are becoming common, and it would not therefore be difficult in many cases to collect several of them, and by combining them, obtain results, never before reached by any method, for the development of statical electricity.

Steam Rollers for Roads.—The employment of these machines in Paris has been noticed before in this *Journal*, and we would now mention that they are also receiving successful application in England.

Some time since Messrs. Easton, Amos and Anderson made a set of rollers for the new park of Mr. Hanbury, which were drawn by a traction engine built by Messrs. Averling & Porter; but in the course of operation, it was found that the effect produced by the wheels of the traction engine was as good as that of the roller, though the latter weighed fifteen tons. A traction engine, with wheels three feet broad, was therefore built and used for the purpose. A short time since, another of these engines, or rather steam rollers, was made for the borough of Liverpool, and on its trial, at Hyde Park, was found to operate in the most satisfactory manner. The wheels or rollers of this machine were seven feet in diameter, two feet six inches on the face, and weighed nine tons each.

The Carbon Smee Battery.—It is well known, no doubt, to most of our readers, that a platinized carbon plate may be substituted, with excellent effect, for the silver in Smee's Battery. In a letter received lately from C. T. Chester, of New York, we find the

following practical evidence upon the subject: "I examined the Cooper Institute Battery, a few days since. It is six cells of carbon Smee, in nine-inch stone pots. It goes up and down by cords and pulleys. It gives a nine and a quarter-inch spark from the old Ruhmkorff, which is now practically its fullest extent. This battery, with about two charges of sulphuric acid and water, does all the amount of lighting up their hall by the spark and all the experiments during the course pertaining to the coil, as well as all of those shown to visitors from time to time for one year.

We are also doing a great deal here with the large flat carbon plates in Smee's batteries for electrotyping. All Harpers', and Tract and Bible House work is done by them.

A Locomotive for Common Roads has been patented in England, in which the tires are made of soft vulcanized india rubber. It is stated that this enables it to pass over ruts, cobble-stones, ploughed fields and grassy lanes with equal facility. One of these engines was lately constructed by Mr. R. W. Thompson, of Edinburgh, and on its trial was reported to behave in a most satisfactory manner.

Les Mondes and M. l'Abbé Moigno.—We notice with pleasure the great improvement that has shown itself in this journal, since it has been under the management of our friend and correspondent, M. l'Abbé Moigno, who for the last twenty years has indefatigably worked in the cause of science, both by his own researches and by his literary labors, in recording, and thus immortalizing, the works of others. As co-editor of the *Cosmos*, he for many years contributed largely to the support and reputation of that renowned journal.

For reasons which we will not here discuss, his connection with this publication has ceased, and he has since thrown all his energy into *Les Mondes*, which manifests conspicuously the scope and character of his genius, and does credit to his varied ability. The last numbers which we have received are full of interest, and replete with instruction. They contain numerous engravings of new apparatus, beautifully executed and accompanied by lucid explanations, notes of all scientific novelties generally, abstracts of the proceedings of learned societies, and interesting comments on the topics of the day.

Carbonized Paper.—We have, on a previous occasion, mentioned the invention designated as above, and made some months since by Mr. J. E. Hover, of this city, and we now again call attention to the fact, that at the last meeting of the Institute samples of

all forms of writing paper, such as note and letter sheets of various sizes and envelopes, as well as varieties of printing paper, were exhibited, and thus the actual progress of the practical realization of Mr. Hover's plan was indicated.

The carbonized paper, as we have before remarked, is simply paper so charged with an earthy carbonate, that the ink, containing as it does sulphate of iron and gallic acid, reacts by formation of sulphate of the earth and the black per-gallate of iron, so that even if the ink is of the palest possible description, it becomes intensely black on contact with the paper.

In addition to this, the mineral sulphate formed acts as a mordant, attaching the ink more firmly to the paper, and also, by reason of the entire neutralization of the free acid of the ink, the risk of fading in the writing or decay of the paper is greatly diminished if not entirely removed.

The mineral matter employed in surfacing the paper has also a marked effect in preventing "greasiness," and in causing the ink to flow freely and pleasantly in writing.

It is also stated, that, for a like reason, this paper will also take the printing-ink more readily, and furnish a blacker and smoother impression.

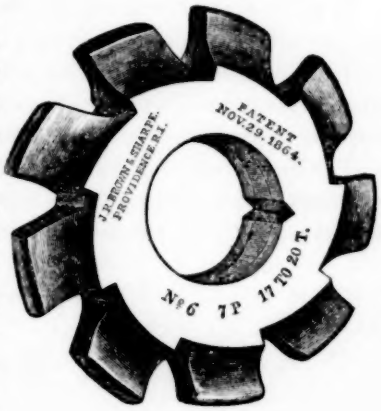
The Suez Canal.—By the last advices, we hear that a steam-tug, the English government vessel *Prompt*, has been actually floated through from the Mediterranean to the Red Sea.

She was lightened in every way possible, even to the removal of her side-wheels, and then, with the aid of sundry empty casks, at last "bumped" safely through.

Specialties in Tool Making.—Under this head, we discussed in our November issue, several improvements in cutting-tools and other instruments, and in our December number gave an abstract of an extensive article published in Engineering, bearing upon the same subject (p. 366). We now call attention with pleasure to another of the many existing improvements in *tools* used for the manufacture of *tools*, this being the *Cutters for Teeth of Gear Wheels*, by Brown & Sharpe, Providence, R. I. We give from the catalogue issued by this firm the following excellent description:—

While improvements have been made in almost every other tool in common use, there seems to have been no change for the better in the construction of cutters for the teeth of gear wheels, which, as every machinist knows, are troublesome and expensive to make

and last but a short time, as they soon become dull and then require to be annealed, re-cut and hardened again, the cost of which is nearly equal to that of making new cutters, while the steel is liable to injury from repeated heating.



To overcome these difficulties, a cutter has been made, as shown in the engraving, by constructing the teeth or blades in the form of segments or curvilinear sections that are mechanically accurate in outline and of equal size and contour throughout their entire length, each of which has a sufficient circumferential inclination with respect to the revolving circumference of the cutter to produce the proper degree of clearance, so that the tooth may be sharpened by grinding away its face until its strength is permanently impaired, so that it will always present the same cutting contour, each new face and cutting edge produced by grinding being a fresh radial section of an equi-form tooth throughout its whole length.

A cutter made on this plan will outlast many of the old form, with the advantage of being always ready for use. If, as frequently happens, the cutter becomes dull before a wheel is completed, it can be taken out, sharpened, and returned to its place in a few moments, without any risk of altering the form of the teeth to be cut.

A Bridge across the Lehigh River has been constructed, connecting the towns of Bethlehem and South Bethlehem, and was opened to the public on Monday. It is one thousand and sixty feet long and thirty-four feet high from low water-mark, and extends across the railroad track of the Lehigh Valley and the Lehigh and the Susquehanna Railroad Companies, the Lehigh Canal, the Lehigh River, and Monocacy Creek. It is a great improvement, and will be generally used in preference to the old bridge, as all obstructions and dangers from crossing the several railroad tracks will be thereby avoided. Its cost was $60,000.

Tunnel across the Sierra Nevadas.—The great tunnel of the Central Pacific Railroad, at the summit of the Sierra Nevada Range,

is opened. The track is being laid on the Eastern slope, a locomotive is already running in the Truckee Valley, and in a few days the road will have reached the open country of the Salt Lake Basin, after which progress will be rapid and easy. This overcomes the only noticeable obstacle on the western portion of the through line, and its significance is understood when we are told that the cost and difficulty of grading the 150 miles now nearly completed, is greater than for the 650 miles next following. The Chief Engineer expects to average a mile a day across the interior valley next year.

The local traffic on the completed portion surpasses all previous estimate, and is lucrative without the immense through business which we may expect to flow over it.

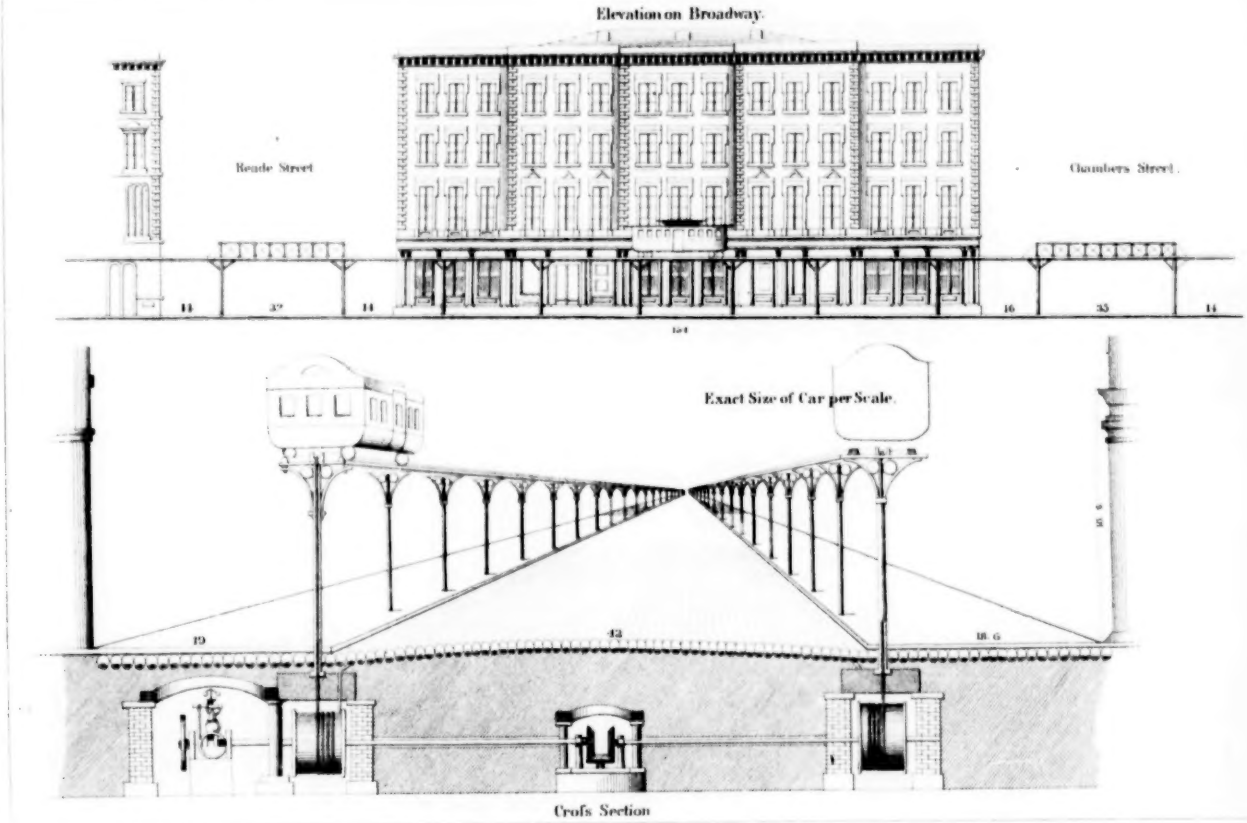
Editorial Correspondence.

WEST SIDE AND YONKERS ELEVATED PATENT RAILWAY.

NEW YORK, *December*, 1867.

THE experimental half mile authorized by act of Legislature last winter, is nearly completed, and its construction has become a matter of public observation. In obedience to my promise made some weeks back, I propose now to describe its design and method of working. The line starts corner of Greenwich street and the Battery, and is now finished up to Rector street, a distance of some 1500 feet. If the present experiment proves a success, the line will be continued this winter up Ninth avenue to the Hudson River Railroad depôt, corner of Thirtieth street, with the eventual idea of extension to the village of Yonkers, on the Hudson, *via* "King's Bridge." Should results warrant the further introduction of this system, a middle route up Broadway, as also an east side one as far as New Rochelle, on the Sound, are embodied in the schemes of the projectors.

The mode of construction is a very simple and elegant one, being unobstructive and open. The supporting principle, following the line of the curbstone, consist of *single* wrought iron columns, as made under the patent of the Phœnix Iron Company of Philadelphia, about fourteen feet high, with the segments spread out in a graceful curve, to which the cross-heads for supporting the rail-girders are attached. These are four-segment eight-inch columns,


Elevation on Broadway.
Reade Street
Chambers Street.
11
37
11
16
35
11
154
Exact Size of Car per Scale.
19
43
18. 6
15. 6
Crofs Section

with a thickness of metal of three-eighths of an inch. This form, by the way, will be recognized from my October letter. They will be spaced twenty-five feet apart from centre to centre, as near as may, thus necessitating simple girders to span the interval. These girders are composed of eight-inch deck-beams in pairs, packed with a timber scantling, to which the rails are spiked, thus acting as an absorbent and cushion for the shocks of the traveling load. Beyond their fastening on the cross-heads of the columns, nothing more is required but simple stay-rods, to prevent the spreading of the rails and girders. The foundations are made stable by means of spreading out the segments at the base of the columns, in a similar manner as was noted above. A heavy casting, with necessary lugs and ribs upon it, is made to fit the under surface of the segments thus swelled out, to which they are securely bolted. This casting, by means of its broad, flat base, is in turn bolted to a very heavy under-casting secured to a well-bedded masonry pier ten feet deep, by means of long bolts running the whole length of the masonry, and firmly anchored therein. Between the rail-girders a small covered square trough, with a slot on its *upper* side, is placed, returning under the street in the axis of the roadway, and of course through the masonry piers, into which it is carefully built. This completes in the main what you may call, if you please, the inanimate construction.

The motive power will consist of stationary engines at *every* half mile under the side-walk, each one operating a large single drum six feet in diameter, ingeniously contrived to accommodate *two* ropes of contiguous sections. The sections being so short, steel-wire ropes of but one-half inch in diameter will be used, thus obviating what has always been considered an insurmountable difficulty. While on the subject of propulsion by an endless rope, it might be interesting, historically, to call attention to the fact, that English engineers and others had tried and given the system up as expensive and impracticable. It was adopted many years ago on the London and Blackwell Railway on a level track. Here a single rope was used in a length of several consecutive miles, requiring a diameter of something like five inches. A good speed was gotten up, but the clumsy character of the rope and the seeming impossibility of a satisfactory attachment and relief of the rope while in motion, caused an abandonment of the idea. In 1847 a plan was endorsed by the Mechanic's Institute, New York, of an endless belt elevated railway,

and an experimental section was actually built encircling the Crystal Palace, but was destroyed by the same fire that brought that building to the ground. Most American engineers will remember Professor Gillespie's views on this style of railways, in his manual of "Roads and Railroads." In the line before us, the plan pursued, as above mentioned, requires a small rope, thus obviating one difficulty, the cars passing from one section to another by means of their own momentum. The gap thus caused is not over twenty feet, so that at a speed of say ten miles an hour, the resistance to progression must be inappreciably small. At proper intervals the rope will be attached to what you may call small "universal trucks" about two feet long—universal in the sense that in no matter what position they may be put, friction rollers will always be presented to roll upon. Upside down or sideways, they will roll, in addition to which, the attachment of the rope is by means of swivel-joints, so that no kink or twist can arise. A strong finger, as it were, projects above the slot mentioned in connection with the middle box in which it runs. To this the car is attached. The construction of the cars become, perhaps, the vital point in this scheme; but so far as competent engineering judgment can discern, no mechanical device has been neglected that promised to insure success. Experimenting alone will tell the tale, and to that end New Yorkers are looking with anxious interest. The difficulty is just here—a rope is running say at a speed of ten miles an hour, with nothing visible but the little fingers of the trucks—to these fingers the cars must be attached or detached, without slacking the rope and without producing a shock on the car or its passengers; it must slow up in stopping, and gradually get headway in starting. It would hardly do to jump at once at full speed; it would rack everything to pieces. The slowing up after detachment will be a matter easily regulated by brakes; but how to store up sufficient momentum to get under headway before making fast, is the *experimentum crucis* beyond which all other difficulties are but trifles. The first experimental car will be about 30 feet long, with a long barrel placed immediately below the floor, running the full length of car, surrounded with a stiff spiral spring. Secondary springs of india rubber are attached to the spiral spring and the body of the car, running in an oblique direction. The shock of contact will be taken up on the springs, which force is stored up by another set of springs, to be used in *starting* the car for the next station. Attached to the spiral, and sliding on the barrel, the imme-

diate attachment is effected by means of a lever operated by the attendant in charge of the car.

Of course there must be an up and down track on either side of the way, with landing at proper intervals for passengers to get on or off. It is proposed to use the second floors of the buildings along the route, whenever needed, the entrances being the ordinary ones proper to any street building. The estimated cost is $250,000 per mile, which experience shows, on the portion now building, to be amply sufficient. The projector, patentee, and engineer is Mr. Chas. T. Harvey, whose plans have been faithfully executed by the Phœnix Iron Company, who can take an honest pride in their work as exhibited along Greenwich street.

I hope to be able to give at some future time full drawings, showing the mechanical devices of the scheme, but for the present merely illustrate this sketchy notice by means of a couple of diagrams showing the street appearance and the general arrangement of the motive power. Taken in connection with the text, I trust the principal features of this scheme will be made fully apparent.—A. P. B.

CENTRAL RAIL LOCOMOTIVES.

Professor Henry Morton.

DEAR SIR:—Will you allow me to correct a slight error, which I observe on page 320 of your November number? My friend Mr. Coleman Sellers is there stated to have made the following remark, when speaking about the centre-rail engine for railroads:—"The person to whom Professor Morton alluded was Mr. Trautwine, the Engineer of the Panama Railroad, who advocated the use of this plan across the isthmus. The engines were built; but the engineer who succeeded him concluded to cut down the road, and use common engines." The error consists in this: That I never contemplated the use of such engines on that road, further than as a temporary resort, while making the summit excavations; and even that idea originated with the board of directors, who were determined to leave nothing unprovided for that could expedite the work. I expressed to them the conviction that no such precaution was necessary; but inasmuch as it would at least do no harm, the directors requested their consulting engineer (Horatio Allen, Esq.,) and myself to wit-

ness some experiments with a large working model engine, prepared by Mr. George Escol Sellers, its inventor, and to report upon the result. We did so, and our report was unqualifiedly favorable, and the engines were accordingly ordered. This was at about the middle of 1850. They were not used on the Panama road, simply because, as I had predicted, no necessity for them presented itself; and my co-engineer and friend Col. Totten, who remained upon the road after I had resigned, employed them as common engines. A centre-rail engine had been patented in England in 1830 or 1831, by Errickson & Vignoles; but Mr. Sellers's engine combines self-acting means for adjusting the adhesion to suit both the grade and the load, with other peculiarities, which renders it so far superior to that of Errickson & Vignoles, that it must be regarded as essentially a new and original invention. About thirteen years since, as Engineer of the New York and Middle Coal Field Railroad, I recommended the use of the Sellers engine on a grade of 150 feet per mile; and the directors (the late city Postmaster, C. A. Walborn, Esq., President), notwithstanding the unfavorable opinions universally expressed by other engineers, and by locomotive builders, procured from Mr. Sellers two very powerful ones. Financial troubles, however, led to an abandonment of the road, and the engines were sold at very low prices to other coal companies. As none of the officers of these companies understood the principle or mode of action of the engines, they did not even make a trial of their capabilities, although it might have been done, and the grand problem satisfactorily demonstrated to all, for a few hundred dollars. As the worthy president of one of the companies himself complacently informed me, "We are all practical men on this road, and don't believe in thy gimcracks." The centre-rail machinery was accordingly taken off and melted up for castings; and thus Mr. George Escol Sellers was deprived of the honor of having his name associated with the first practical success of this invention—an honor ascribed to the inventor of the very inferior machine which is now daily hauling trains across the Alps. The day may perhaps come when the Sellers engine will in like manner cross the Rocky Mountains. In these few lines you have the entire history of the centre-rail engine in this country.

Yours, truly,

JOHN C. TRAUTWINE.

Philadelphia, Dec. 6, 1867.

Civil and Mechanical Engineering.

ON THE TRANSMISSION OF FORCE BY BELTS AND PULLEYS.

THERE are few mechanical engineers who have not been frequently in want of tabular information or readily applicable formulæ, upon which they could place reliance, giving the power which, under given conditions and velocity, is transmitted by belts without unusual strain or wear. The formula of the belt or brake is well known and simple, and it is only necessary to acknowledge and adopt a value for the co-efficient of friction (or of adhesion, which is perhaps the better term), to allow this formula to be applied in daily use. And this co-efficient of friction has been carefully established by the experiments of General Morin and M. Prony, and has been made available to English and American engineers, by the translation of Bennett.*

With every point needed, therefore, at the command of the engineer, it is somewhat surprising that a more extensive publication and general use of the data has not followed.

But notwithstanding the existence of this correct mathematical and experimental information, the numerous tables which have been given by mechanical engineers appear to have had only that kind of practical basis which has come from guessing that an engine or a machine, either the driving or the driven, with a belt of given width, was producing or requiring some quantity of power which might be expressed in terms (foot-pounds) generally without any stated arc of contact. Three rules given by practical mechanics, vary so much as to give as bases for estimate (without regard to arc of contact) 0·76 horse-power, 0·93 horse-power, and 1·75 horse-power, respectively, for the power of a belt one inch wide running 1000 feet per minute.

It was the requirement to know the exact useful effect of a novel disposition involving an unusual small arc of contact of the belt upon the pulley, where much embarrassment would result if the application proved itself unsatisfactory that led to the present inquiry. As the writer was not able to give the time demanded for making such

* Bennett's *Morin's Mechanics*, New York, 1860.

It must be remarked that there are some mistakes in the text of Bennett's translation, which will lead to serious errors, unless read by a careful investigator.

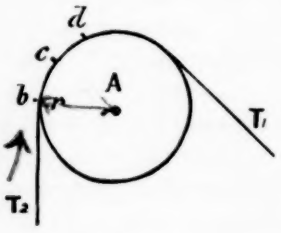
experiments as would establish the practical co-efficient of adhesion, he suggested what was desired to Mr. H. R. Towne, and the numerous experiments, of which he gives the accompanying report, are the result of his labor and care.

It was not until after the experiments were completed, that either Mr. Towne or the writer knew of the publication of M. Prony or General Morin, although Bennett's translation rested upon the shelves of the writer's library; but aside from the gratification which we feel at the corroboration, we think the reader of this article will be pleased to know that our data is founded upon the ordinary pulleys and belts of the workshop, and our experiments were not impaired by any niceties which common workmen would not apply.

Even the crudeness of our experimental apparatus and the general not over exact method adopted, will serve to demonstrate to the minds of practical men the possibility of relying upon figures which have been established so nearly in accordance with the customs of the workshop.

We take from Rankine's *Applied Mechanics* the following formula of a belt, only changing the words in the hope to make it comprehensible to the general reader in an elementary way.

Let A be a pulley upon which the belt passes from T_2 to T_1. Let r = the length of radius of the pulley A. Let T_1 = the tension of the belt (or the strain) on the tight side. Let T_2 = the tension of the belt (or the resistance on the loose side). Then the pull on the belt by which it transmits power = $P = T_1 - T_2$, and this difference represents the adhesion or friction resulting from the contact between the belt and the pulley.



If we suppose the tension on a unit of width of belt at $b = T_2$, then it follows that the normal pressure per unit of surface at the point $b = \frac{T_2}{r}$. The units of dimension, either linear or superficial, may be inches and square inches, feet and square feet, metres and metres square, or any other units of relative value. Thus we may say the normal pressure upon a square inch of surface at b, equals the tension on an inch-wide belt T_2, divided by the length in inches of the radius r.

We will endeavor to make this understood by comparing the case

with the well-known instance of the relation of pressure to tension in the shell of a cylindrical boiler. If we take an example of a boiler having 10 inches radius (or 20 inches diameter) and with an internal uniform pressure of 100 pounds per square inch, it will be recognized that the tangential strain per inch of length of shell will be equal to the pressure multiplied by the radius, or 1000 pounds; and this tangential strain is uniform at all points of the circumference.

The tension T_2, in like manner, corresponds to the tangential strain just stated, and the resulting normal pressure corresponds to the internal uniform pressure. And as in the instance of the boiler the tangential strain is exerted at all points of the circumference, so the normal pressure proceeding from the tension in the case of a belt, is independent of the length of arc of contact on the belt, and refers to the point of contact b, wherever that point may be taken on the pulley.

Admitting, therefore, that the pressure at the point $b = \frac{T_2}{r}$, we have the friction resulting from the contact of the belt on a unit of surface $= f\frac{T_2}{r}$ (when f is the co-efficient of friction of the leather of the belt on the pulley. This gives a new value for the tension of the belt at some point, c (very near b), (or tangential strain at that point), $= T_2 + f\frac{T_2}{r} = T_2\left(1 + f\frac{1}{r}\right)$. And it follows that the pressure at $c = \frac{T_2}{r}\left(1 + f\frac{1}{r}\right)$, and the friction resulting from the contact of the belt on a unit of surface $= f\left[\frac{T_2}{r}\left(1 + f\frac{1}{r}\right)\right]$ This again gives a new value for the tension of the belt at some point, d (very near c) $= T_2 + f\left[\frac{T_2}{r}\left(1 + f\frac{1}{r}\right)\right] = T_2\left(1 + f\frac{1}{r}\right)^2$ On taking further points in succession until we take l points and reach the point m on the figure, we have for the tension at $m = T_2\left(1 + f\frac{1}{r}\right)^l = T_1 \therefore \frac{T_1}{T_2} = \left(1 + f\frac{1}{r}\right)^l$

This equation is the well-known one of the hyperbolic logarithm. Where hyperbolic logarithm $\frac{T_1}{T_2} = f\frac{l}{r}$ or $\frac{T_1}{T_2} = e^{f\frac{l}{r}}$, where e is the base

of hyperbolic logarithms. We can further transform this equation by substituting the ratio of the angle in degrees, for the length of contact on the arc, compared to the radius.

$$\text{Thus } \frac{2r\pi}{360} = \text{arc of } 1°, \text{ let } l = a\left(\frac{2r\pi}{360}\right) \therefore \frac{T_1}{T_2} = e^{f\frac{2\pi a}{360}},$$

and taking the numerical values of e, π, and dividing out the 360,

$$\therefore \frac{T_1}{T_2} = 2{\cdot}718^{0{\cdot}017456\,fa}$$

$$\therefore \log.\left(\frac{T_1}{T_2}\right) = 0{\cdot}4343\ (0{\cdot}017456\,fa), \tag{1.}$$

$$\therefore \log. T_1 - \log. T_2 = 0{\cdot}00758\,fa$$

$$\therefore \frac{T_1}{T_2} = 10.^{0{\cdot}00758\,fa}, \tag{2.}$$

$$\therefore f = \frac{\log.\left(\frac{T_1}{T_2}\right)}{0{\cdot}00758\,a} \tag{3.}$$

As we assumed before, $P = T_1 - T_2$. $\therefore T_2 = T_1 - P$, which inserting in equation 2.

$$\therefore \frac{T_1}{T_1 - P} = 10^{0{\cdot}00758\,fa}$$

$$\therefore P\left(10^{0{\cdot}00758\,fa}\right) = T_1\left(10^{0{\cdot}00758\,fa}\right) - T_1$$

$$\therefore P = T_1\left(1 - 10^{-0{\cdot}00758\,fa}\right) \tag{4.}$$

The third equation is the one to which we would now call attention. By it, for any given values for the ratio $\frac{T_1}{T_2}$, we can determine the co-efficient of friction, when, by experiment, we have fixed the greatest difference of the two strains without slipping on a pulley with a given arc (measured by a) of contact.

We would here make a very important observation, which forms the key of the whole system of transmission of force by belts. In practice, *all belts are worked at the maximum co-efficient of friction.* A belt may, when new or newly tightened, work under heavy strain and with a small co-efficient of friction called into action; but in

process of time it becomes loose, and it is never tightened again until the effort to perform its task is greater than the value of the co-efficient with a given tension of belt, and the belt slips. We run our belts as slack as possible, so long as they continue to drive.

It has been shown* that the value of $T_1 + T_2$, or the sum of the strains upon the two sides of a belt (loose and tight), is a constant quantity—that is, when a belt is performing work, it will become loose on the one side to the exact amount that it is strained on the other, and when at rest, not transmitting force, the tensions will become equal, and their sum be the same as before. It is manifest that the limit of the strength of a belt is found in the maximum tension T_1, and that this strength being known, the effective pull (P) is further limited with any given arc of contact by the value f of the co-efficient of friction.

The discussion has so far been limited to the pull exerted by a belt; when we would include the power which belts will transmit, we have only to multiply the pull by some given or assumed velocity, to transform our equations into work performed.

By means of the third equation, we will now deduce a value for the co-efficient of friction as given by the experiments.

All the experiments were with the arc of contact $=180°=a$,

$$\text{which, substituting } f=\frac{\log.\frac{T_1}{T_2}}{1{\cdot}3644}$$

and the result of 168 separate experiments has given, under tensions of T, from 7 to 110 pounds per inch of width of belt, $\frac{T_1}{T_2}=6{\cdot}294$.

$$\therefore f=\frac{\log.\ 6{\cdot}294}{1{\cdot}3644}=0{\cdot}5833.\dagger$$

In this case T_1 has in all cases been so much in excess of T_2, as to slip the belt at a defined, slow but not accelerating, motion.

From an examination of the report of the experiments, we think the reader will coincide with our conclusion that $\frac{6}{10}$ of this value of $\frac{T_1}{T_2}$ can be taken as a suitable basis for the working friction or adhe-

* Bennett's Morin, page 303, and following ¶ 252.

† Bennett's Morin, page 306, ¶ 253, gives $f=0{\cdot}573$.

sion which will cover the contingencies of condition of the atmosphere as regards temperature and moisture; or

$\frac{T_1}{T_2} = 3{\cdot}7764$ (maximum practical value) $\therefore f = \frac{\log. 3{\cdot}776}{1{\cdot}3644} = 0{\cdot}42292.$*

The experiments further show that 200 pounds per inch of width of belt is the maximum strength of the weakest part—that is, of the lace holes. Taking this, with a factor of safety at one-third, we have the working strength of the belt, or the practical value for $T_1 = 66\frac{2}{3}$ pounds.† The case when belts are spliced instead of laced, a great increase of strength has been shown, the experiments giving 380 pounds per inch of width, or 125 pounds safe working strength.

If we insert these values of f and T_1 in (4,)

$$\therefore P = 66\tfrac{2}{3}\left(1 - 10^{-0{\cdot}0078 \times 0{\cdot}42292\ a}\right)$$

‡ $$\therefore P = 66\tfrac{2}{3}\left(1 - 10^{-0{\cdot}003206\ a}\right) \qquad (5.)$$

The largest possible angle for an open belt, without a carrier or tightener, is 180°, as upon either the driving or the driven pulley

* It should be noted that the experiments were made without any appreciable velocity of belt, and throughout this paper no regard has been paid to the effect of velocity or of the dimensions of the pulleys upon the value of the co-efficient of friction.

For pulleys less than 12 inches diameter (with the belts of the ordinary thickness of about $\frac{3}{70}$ths inch), and for velocities exceeding about 1000 feet per minute, allowance must be made for the rigidity of the belt in the one case, and for the *interposition of air between the pulley and the belt* in the other. At high speeds, say 3000 feet velocity of belt per minute, the want of contact can be seen, sometimes, to the extent of one-third the arc encompassed by the belt. The writer has proposed to place a deflector or stripper near the belt, to take off the stratum of air moving with it, but has never tried the experiment, although he has little doubt of its giving some advantage.

† Bennett's Morin, page 306, ¶ 253, gives 55·1 pounds per inch of width as admissible.

‡ This equation (5,) is the really important one in practice, and by means of logarithms, can be solved for any values of $a°$ readily; but as some of those who may wish to use it may not be at once prepared to use the logarithmic notation, from want of use or practice, we give an example. Suppose we take an angle of 90°, the negative exponent then becomes—$0{\cdot}003206 \times 90 = -0{\cdot}28854$; subtracting this from 1, we have—1·71146. This term thus becomes $10^{-1{\cdot}71146}$. Now this expression is only the notation for anti-logarithm—1·71146, or in words the number for which—1·71146 is the logarithm. Logarithmic tables give this number = 0·51505, and the equation $P = 66\frac{2}{3}\left(1 - 10^{-0{\cdot}003206 \times 90}\right) = 66\frac{2}{3}\left(1 - 10^{-1{\cdot}71146}\right) = 66\frac{2}{3}$ $(1 - 0{\cdot}51505) = 66\frac{2}{3} \times 0{\cdot}48495.$

$\therefore P = 32{\cdot}33$

this cannot be exceeded, but for crossed, or carried, or tightened belts, the angle may be as large as 270°.

We give the following table of results for different arcs of contact (corresponding to $\alpha°$) within the usual limits of practice.

TABLE I.

Strain transmitted by belts of one inch width, upon pulleys when the arcs of contact vary as the angles of

90°	100°	110°	120°	135°	150°	180°	210°	240°	270°
Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
32·33	34·80	37·07	39·18	42·06	44·64	49·01	52·52	55·33	57·58

If we suppose the pulley to be 1 foot in diameter, and to run some number, N, of revolution per minute, we have the power transmitted $= N \pi P$.

And we give the following table for different arcs of contact (corresponding to $\alpha°$) within the usual limits of practice.

TABLE II.

Power transmitted by belts on pulleys one foot in diameter one revolution per minute. Arcs of contact of belts upon pulleys corresponding to the angles.

INCHES OF WIDTH OF BELT.	90°	100°	110°	120°	135°	150°	180°	210°	240°	270°
	Foot-lbs.	Foot-lbs.	Foot-lbs.	Foot-lbs.	Foot-lbs	Foot-lbs.	Foot-lbs.	Foot-lbs.	Foot-lbs.	Foot-lbs.
1	102	109	116	123	132	140	154	165	174	181
2	203	219	233	246	264	280	308	330	348	361
3	305	328	349	369	396	420	462	495	521	542
4	406	437	466	492	528	560	616	660	695	723
5	508	547	582	615	660	701	770	825	869	904
6	609	656	699	738	792	841	924	990	1043	1084
7	711	766	815	861	924	982	1078	1155	1217	1265
8	813	875	932	985	1056	1122	1232	1320	1391	1446
9	914	984	1048	1108	1188	1262	1386	1485	1564	1626
10	1016	1094	1165	1231	1321	1402	1540	1650	1738	1807

The application of Table II. to any given cases of known angle of the arc of contact, width of belt in inches, diameter of pulley in feet, and number of revolutions, is simply to take the figures from

the table for the first two, and multiply by the two succeeding conditions, to obtain the foot-pounds of power transmitted.

We have taken the following examples:—First. Mr. Schenck (of New York) found an 18-inch wide belt running 2000 feet per minute, the pulleys being 16 feet to 6 feet, would give 40 horse-power, with ample margin (one-fourth). (*Sic.*)

If we take the distance from centre of the 16-feet pulley to that of the 6-feet to be 25 feet (about the usual way of placing the fly-wheel pulley of an engine in regard to the main line of shafting), we have the arc of contact subtending about 153°. From Table I. the strain transmissible is 45·1 pounds × 18 × 2000 = 1,623,600 foot-pounds = 49·2 horse-power.

Second. Mr. William B. Le Van (of Philadelphia) found by indicator that an 18-inch wide belt running 1800 revolutions per minute, the pulleys being 16 feet and 5 feet, respectively, transmitted 43 horse-power, with maximum power transmissible unknown. If we take the centre's distance, as before, at 25 feet, we have the arc of contact subtending about 150°.

From Table I. we derive 44·64 pounds as the strain transmissible × 18 × 1800 = 1,446,336 foot-pounds = 43·83 horse-power. The same authority found by indicator that a 7-inch wide belt over two 2-feet 6-inch pulleys, 11 feet centre to centre (horizontal), moving 942 feet per minute, gave 8 horse-power. From Table I. for 180° angle, we take 49·01 × 7 × 942 = 323,172 foot-pounds = 9·79 horse-power. This belt was stated to be very tight.

Third. Mr. A. Alexander (*London Engineer*, March 30th, 1860) gives a rule that a 1-inch belt will, at 1000 feet velocity, transmit $1\frac{3}{4}$ horse-power.

If we take the contact at 180° from Table I., 49·01 × 1000 = 49,000 foot-pounds, we have only $1\frac{1}{2}$ horse-power.

Fourth. Mr. William Barbour (same journal, March 23, 1860) gives as the power a 1-inch belt will transmit with 1000 feet velocity = 0·927 HP., when we derive with 180° angle from our tables = $1\frac{1}{2}$ HP.

Fifth. A. B. Ex (same journal, April 6, 1860) gives a rule

$$\frac{\text{diameter in inches} \times \text{revolutions per minute} \times \text{breadth in inches}}{5000} = \text{N HP.}$$

ratio of pulleys not to exceed 5 to 1. Changing this rule to

$$\frac{\text{diameter in feet} \times \text{revolutions per minute} \times \text{width in inches}}{5000 \div 12 \div 33{,}000} = \text{N foot-pounds.}$$

$$\therefore \frac{\text{Diameter in feet} \times \text{revolutions per minute} \times \text{width in inches}}{0{\cdot}01263} = \text{N}$$

foot-pounds.

$\therefore$ 79·2 × diameter in feet × revolutions per minute × width in inches = N foot-pounds.

From Table II. the angle of 120° gives 123 in place of 79·2, and it would appear this authority adopts about $\frac{2}{3}$ the effect we take.

Sixth. Dr. Fairbairn gives (*Mills and Mill Work*, Part II., page 4) a table of approximate width of leather straps in inches necessary to transmit any number of horses-power, the velocity of the belt being taken at 25 to 30 feet per second (1500 to 1800 per minute), 1 foot pulley, 3·6 inches wide, gives 1 HP.

Assume 1650 feet per minute, contact 180°, we have from Table I., 1650 × 49·01 × 3·6 × 1 = 29,112 foot-pounds = 0·87 HP.

Seventh. Rankine gives (*Rules and Tables*, page 241) 0·15 as the co-efficient of friction, probably applicable to the adhesion of belts on pulleys to be used with his formulæ in estimating the power transmitted. Neither experiments nor practice give so small a co-efficient as this.

We could multiply authorities on these points, but think the corroboration of those we quote with our tables, sufficient to establish our experimental and estimated co-efficient of friction, $f = 0{\cdot}423$, as a proper practical basis.

We give the two following cases not only to show the application of the formula 5, but as matters of some interest.

In the construction of one of the forms of centrifugal machines for removing water from saturated substances, the main or basket spindle is driven by cone-formed pulleys, one of which, being covered with leather, impels the other by simple contact.

In the particular instance taken, the iron pulley on the spindle was 6 inches largest diameter, and the leather-covered driving pulley was 12 inches largest diameter—the length of cones on the face was 4 inches, this last dimension corresponding to width of belt in other cases. By covering the leathered pulley with red lead, we were able to procure an *impression* on the iron pulley, showing the width of the surfaces of contact when the pulleys were compressed together with the force generally applied when the machine was at work. This width was, at the largest diameters, almost exactly $\frac{1}{4}$ an inch. From the nature of the two convex surfaces compressing

the leather between them, the actual surface of efficient contact cannot be taken at over half this width (the slight error in estimating this contact as straight lines in place of circular arcs may be neglected). This gives the angle subtended by the arc of contact on the iron pulley $= 2\frac{1}{2}°$, taking equation (5). $P = 66\frac{2}{3}\left(1 - 10^{-0.003206\, a°}\right) = 66\frac{2}{3}\left(1 - 10^{-0.008015}\right) = 66\frac{2}{3}\left(1 - 10^{-1.991985}\right) = 66\frac{2}{3}\left(1 - 0.98171\right) = 66\frac{2}{3}\,(0.01829) = 1.3717$.

Now, the average diameter of the iron pulley in the middle of its 4-inch face is 4·708 inches = 0·3923 feet, with a circumference of 1·2326 feet, and it is usual to run, at the least velocity, 1000° revolutions per minute; whence the power given by these pulleys = 1·3717 pounds × 4 inches × 1·2326 feet × 1000 revolutions = 6757 foot-pounds = $\frac{1}{3}$ HP. As the work performed by one of these centrifugal machines is the acquirement of velocity under the resistance of the friction of the machine and of the air, and the work of expelling the moisture is so insignificant in comparison that it may be neglected in estimating, it can be taken as probable that the real power demanded to keep the machine in motion is very nearly that given by calculation. It should be stated that the basket belonging to this particular machine is 29 inches diameter and 12 inches deep.

The second special case we instance at present, consists in a proposed arrangement for driving a fan which had previously been found to demand an 8-inch belt on a 10-inch pulley to run it 1275 revolutions per minute. (The arc of contact here was 162°, so that the apparent power, with a very tight belt, was 37½ HP.; but about $\frac{1}{3}$ of this was defective adhesion from running a rigid belt over so small a pulley.) It was thought desirable to avoid the fast-running countershafts, and drive this direct from an engine-pulley fly-wheel, by impingement, so to speak, of the belt on its tight side between the fan-pulley and another larger carrier pulley, against a portion of the periphery of the fly-wheel.

If we suppose the force demanded measured on the fan-pulley as before, to be 40 HP. = 1,320,000, and the fan-pulley to be 10 inches diameter × 16 inches wide, and to run 1250 revolutions per minute;

$\therefore \dfrac{1{,}320{,}000}{1250 \times 4\frac{9}{2} \times 16 \times \pi} = 25{\cdot}2$ as the pull, P, on each inch of width of

the belt as it comes from the 10-inch pulley. By substituting this value for P in equation (5), and then reducing the equation to find the value for $a°$, we have $a° = 65°$, which is the angle of contact demanded to give the necessary adhesion.

It will be noticed that this angle is independent of the diameter of the fly-wheel pulley, it being only requisite that that diameter should be such as with the given or assumed number of revolutions will produce the given velocity. In the case taken for example, the fly-wheel pulley was 16 feet diameter × 16 inches wide, with 70 revolutions per minute velocity.

As we have before remarked, the sum of the two tensions on the belt is constant, whether the belt is performing work or not;

that is, $S = T_2 + T_1$; but $P = T_2 - T_1$. $\therefore T_2 = T_1 - P$. $\therefore S = 2T_1 - P$.

As we assumed in equation (5) T to equal $66\frac{2}{3}$ pounds, we can substitute the value of P as in Table I. in the equation, $S = 2(66\frac{2}{3}) - P = 133\frac{1}{3} - P$, from which it is evident that the sum of the tensions will vary with P or with the angle of contact. It is evident, also, that the load upon the shaft proceeding from the tensions T_2 and T_1 will be the resultant of whatever angle the belt makes with a line joining the centres of the two pulleys, or as the cosine of that angle.

By constructing on paper a pair of pulleys, it will be readily discerned that the angle in question for small pulleys $= 90° \frac{a}{2}$, and for large and crossed ones, $= \frac{a}{2} - 90°$, we can consequently form the following table:—

TABLE III.

STRENGTH OF LACING OF JOINT $66\frac{2}{3}$ POUNDS PER INCH WIDE,

Showing, first, the sum of tensions on both sides of a belt, per inch of width, whether in motion or at rest, when strained to transmit the maximum quantity of power in general practice: and showing, second, the load carried by the shafts and supported constantly by the journals per inch of width of belt, when the arcs of contact vary as the angles of

	90°	100°	110°	120°	135°	150°	180°	210°	240°	270°
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1st,	101·	98·53	96·26	94·15	91·27	88·69	84·32	80·81	78·	75·75
2d,	71·42	75·47	78·85	81·53	84·32	85·67	84·32	78·05	67·59	53·56

When machinery is driven by gearing, the shafts only carry the running wheels and the weight, and when the machines are thrown on, the friction of the lines increases with the work; but with belts

and pulleys the load on the line and its frictional resistance is constant, whether the machinery works or lies idle.

Of course, it is not proper to assume that the load produced by the belt on the shaft is exactly that given by the second line in Table III.; but we can be safe in taking those weights as rarely exceeded, because belts begin to fail when they are; and as rarely much less, because few of our machines are not worked up to their belt capacity.

The advantages shown by the figures on all the tables, but especially on the last, in those arcs of contact over 180° where crossed belts are used, have the substantial ground of practice, although many mechanics are unaware of the facts. The writer will instance a case of several heavy grindstones having from main to counter lines eight-inch crossed belts on pulleys three feet diameter, running 120 revolutions, only eight feet centre to centre, where belts have already lasted, day and night use, three and a half years. For the same purpose, six-inch open belts were formerly used with an average duration of a few weeks only.

Another use of a crossed belt is for long belts, the crossing effectually preventing those waves which generally impair, if they do not destroy such belts when open.

Besides the actual power transmitted by belts, which it has here been attempted to embrace in a general law, the application of belting, both the manner and the purpose opens a field for discussion far beyond the limits of the present article. The writer, hoping that others will take up the subject, so that the published data of the mechanic may more fully include the practice of the workshop and factory.

AN ACCOUNT OF THE FILLING OF A SINK-HOLE.

By Charles Paine, C. E.

At a marsh about one mile east of Lawrence, upon the "air-line" of the Michigan Southern and Northern Indiana R.R., there occurred, during the construction of the line, a sinking of the embankment which had been nearly completed across the marsh, the fibrous superstratum, of from six to eight feet in thickness, having broken off at each side of the bank, letting the whole drop into a lake of semi-fluid peat below. Efforts at filling up the hole were continued for a long

time; but making very little show for the amount of material absorbed, the work was finally abandoned, the track having been carried around the edge of the marsh by very sharp reversed curves. The inconvenience of this interruption of the straight line, and the destruction of rails on these curves, became considerable, as the traffic of the road increased, and it was thought very desirable to complete the embankment across the marsh. Upon sounding, the peat-bed or lake was found to be about forty feet deep, or from grade about forty-five feet to hard bottom, for a distance of about thirteen hundred feet;—where the embankment had once been built the soundings were only from ten (10) to twenty (20) feet below grade; but at two places, two hundred and three hundred feet long, respectively, no filling had been done.

As the only earth to be procured in the vicinity was a clay which would stand in water at a comparatively low angle, it was evident that an earth bank would require a large quantity, even where a core had already been formed by the work previously done, to complete the slopes. I therefore determined, for that portion of the bank under water, to use materials always at hand upon railways, viz: the decayed sleepers removed from the track in the course of repairs.

The height of grade above the water being five feet, a platform thirty-five feet in width would carry an embankment fourteen feet wide at grade, leaving a leerme three feet wide at each foot of the slopes; such a platform was accordingly laid down and then built upon, each course sinking those below it, until the bottom was reached, the succeeding layers crossing each other, the sleepers also breaking joints longitudinally and alternately, so as to bind the whole together as firmly as possible, keeping the outer edges of the platform somewhat higher than the middle, so as to give the outside sticks a tendency towards the centre.

This work was begun during the winter of 1865–6, and completed during the next winter, at times when the working-train could best be spared for such labor, the earth filling and ballasting having been done during the past summer. Some difficulty was experienced from the slow settling of the platform through the peat, at the points where no earth embankments had previously been made, as the bank which was first made upon the sleepers sunk the platform too far below water, where the earth had to be removed and the platform raised with additional courses of sleepers; but the whole appears

now to have reached the bottom. The trains have been running over the new line for about two months, and the settling is not greater than upon any new embankment. The economy of this mode of forming the bank will be seen to have been considerable, the estimated cost of an earth bank having exceeded $30,000, while the cost of this construction has amounted to not quite one-third of that sum.

BRIDGE OVER THE ALLEGHANY.

THE bridge of the Pittsburgh, Fort Wayne and Chicago Railroad over the Alleghany River, is now completed. An interesting account of its construction we extract from the *Pittsburgh Gazette*:—

The magnificent iron bridge over the Alleghany River, which has been under course of erection by the Pittsburgh, Fort Wayne and Chicago Railway Company for some time past, has been completed, and our city can now boast of two of the finest and most substantial viaducts in the country. The new structure is a most important one, forming as it does a permanent connecting link for one of the greatest highways of travel and trade centering in this city, and, in regard to the manner of its construction, the materials used, and the difficulties which had to be surmounted in prosecuting the work, may be looked upon as a triumph of engineering skill.

The following comprehensive description of the bridge, for which we are indebted to T. D. Messler, Esq., and other officials of the company, will be read with interest.

The bridge which formerly crossed the river at the point occupied by the new bridge, was originally built by the Ohio and Pennsylvania Railroad Company, to complete their connection with the Pennsylvania Railroad at Pittsburgh. The foundations were begun in the month of August, 1854, and the bridge finished in September, 1857, by the Pittsburgh, Fort Wayne and Chicago Railroad Company, of which the Ohio and Pennsylvania Railroad was one of the consolidated companies.

The original superstructure for double track was of wood, on the Howe truss plan, with arches for additional strength. The increased traffic on the railway, and with it the larger wear and tear occasioned, in addition to the bridge not being properly protected in the first years after its erection, made it a necessity at a very early day (considering the importance as a main line of trade and travel between

the East and West, which the Fort Wayne Railway had acquired) to provide for its reconstruction.

In the fall of the year 1863, the then Chief Engineer of the Railway Company, John B. Jervis, Esq., after careful examination, submitted and recommended for approval of the President, George W. Cass, Esq., the present plan, an entirely wrought iron structure, designed and calculated in regard to strength in all its details by Felician Slataper, Engineer and Architect of the company, under whose immediate superintendence the work has been executed.

The plan having, during the following winter, been adopted, a contract was made with Charles J. Schultz, of Pittsburgh, for the construction of its iron work, which was commenced in the spring of the year 1864.

The original structure consisted of seven spans of various lengths, being in all 1172 feet long. On account of the peculiar form and location of the company's freight yard at Pittsburgh, between the bridge and Penn street, it was found necessary to place the switches, that connect the large number of tracks in their yard, as far as possible out on the bridge, in order to use the ground in the most economical and advantageous manner, and to facilitate the lengthening of these tracks for the contemplated new and large freight houses required for the better accommodation of the constantly increasing business of the Railway Company.

To accomplish this, an additional pier 101 feet long was built on the wharf, under the first span on the Pittsburgh side, and the abutment extended parallel with the river, along Duquesne Way, to 148 feet in length. By this arrangement the bridge as now constructed, opens gradually like a fan towards the Pittsburgh freight yard, being at the narrowest part, next to the main span, 55 feet in width, and extending out for 176 feet in length, to the point where it connects with the yard, where the width is 138 feet.

The surface thus gained being equivalent to nearly two-fifths of an acre of additional ground, is covered over between the rails with three-inch oak plank fastened on the solid oak floor beams of the bridge, which are placed 18 inches apart.

For symmetry and economy in the construction, another pier was also built on the wharf at the Alleghany city end span of the bridge.

At both of these end spans the tracks are now supported from below by strong iron plate girders, made entirely of plate and angle iron, all well riveted and substantially braced together.

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For symmetry and economy in the construction, another pier was also built on the wharf at the Alleghany city end span of the bridge.

At both of these end spans the tracks are now supported from below by strong iron plate girders, made entirely of plate and angle iron, all well riveted and substantially braced together.

The two western spans have each three girders 89 feet in length and 6 feet 6 inches deep, to support the double line of railway, the middle one being made proportionately stronger. On the two eastern spans, which form the above-mentioned addition to the yard, eighteen iron plate girders, varying in length from 86 to 93 feet, all 6 feet 1 inch deep, are placed, distributed according to the tracks they are intended to spuport.

The five large spans over the main part of the Alleghany River are built for a double line of railway, with one projecting foot-path on the outside, consisting of three main girders, one on each side and one in the centre, between the ways.

The average length of the spans is 153½ feet in the clear, with a bearing of 5 feet on each pier.

The depth of the girders is 19 feet. The clear width between the outside and the central girders is 14 feet, except the south part of the first main span, where it widens from 14 feet at one end to 32 feet at the other.

The top and bottom sections of the girders are in the form of the letter T, but they, as well as all other parts, are carefully arranged so as to insure, as much as possible, uniform strength for the bridge throughout, in proportion to the effects produced upon it by the load. The cross-sectional area of the top chord consists of four thicknesses of iron laid one over the other, well riveted, and forming together a plate 2¾ inches thick and 24 inches wide in the centre part of the girder, and diminishing gradually to about two-thirds its cross-section at the ends, where it rests on the piers. In addition to which there are two large angle-irons 5 inches by 3½ inches by ⅞ inch to ½ inch thick, and two vertical bars 12 inches by ½ inch on the inside between the angle-iron, running along the centre of the horizontal plates which form the top and bottom portion of the girders, to which they are attached by two of the angle-irons, the other two serving to join the flanges to the bars, which form the vertical web.

The cross-sectioned area of the bottom chords consist of three thicknesses of iron, well riveted, forming together a plate, in the centre part 2¼ inches thick and 27 inches wide, the balance of the construction being similar to the top chord.

The vertical web is composed of lattice work, which is framed with two sets of bars six inches wide, crossing each other and inclined to the top and bottom at an angle of 48°, and forming a net-

work, the distance of the crossing apart being 2 feet 1 inch between the centres of the rivets, measured along the bars, the thicknesses of the bars increasing from $\frac{1}{4}$ inch at the centre part to $\frac{5}{8}$ inch at the ends of the girders. They are secured at their crossings by two rivets. The lattice work is stiffened by vertical angle-irons fixed double on both sides, at distances of about 8 feet apart.

The central girder has about $\frac{1}{3}$ more iron in the cross-section than the outside girders.

All the iron work is well braced and tied together above and below, by a system of transverse and diagonal rods.

The ways inside, to insure proper elasticity, are supported by white oak floor-beams, at intervals of 2 feet apart between centres, on which the steel rails for the railway are fastened.

The following amount of iron was used in the twenty-four plate girders of the end spans, including bracing, tie-rods, &c.

	Pounds.
Plate iron	540,900
Bar iron	69,800
T and angle iron	142,600
Rivets	45,400
Cast iron bed plates	49,300
Total	848,000

The five main spans of lattice girders contain:—

	Pounds.
Plate iron	1,190,600
Bar iron	592,100
T and angle iron	718,600
Rivets	133,000
Cast iron bed plates	73,700
Total	2,708,000

Over 350,000 rivets (each of which was required to be made red hot before they were driven home in their respective places) were used to connect together the above-described 1778 tons of iron.

The cost of the iron bridge superstructure proper, was $435,000.

The total cost, including additional masonry, temporary support of tracks, and other incidental expenses, $530,000.

The iron, of a superior quality, has been purchased for the whole structure, from Messrs. Jones & Laughlin, of the American Iron Works of this city.

The principle of the construction is known as the latticed-girder

plan with vertical stiffenings, and the structure is believed to be the only one of the kind in the United States, although the principle is used very extensively in modified forms on the German, Russian, and Italian railways.

TESTING STEAM-BOILERS.

By S. W. Robinson,

Assistant Professor of Mining Engineering and Geodesy, University of Michigan.

It is generally believed that steam-boilers become weakened, for resistance to internal pressure, after continued use, from various known and unknown causes; so that the engineer cannot judge of the pressure to which his boiler can be worked with safety. But this he may determine by a very simple process, and means which are always at his command. It is as follows:—Let the boiler be filled entirely full of cold water, even to the throttle and safety-valves, and all closed tight to prevent any escape. Now, by lighting a fire under the boiler, the water will be gradually expanded, and produce a pressure sufficient even to rupture the iron before the temperature of the water arrives at the boiling point. While the pressure is increasing, let the steam-gauge or pressure indicator be watched; and when the test pressure, which may be twice or more times as great as the working pressure, is reached, a portion of the water may be allowed to escape and the pressure reduced. The pressure results from the fact that water is expanded more by heat than iron. The process above given is attended with as much safety as the use of the hydrostatic press, unless the water be heated above 212°, which would not be required unless the boiler leaks. Below this temperature no disastrous consequences would follow, even if the boiler should be torn asunder, inasmuch as explosions result from the sudden expansion of gases or vapors.

Ann Arbor, Michigan, December 9th, 1867.

The Wilmington and Reading Railroad, which is to be built during the present year, starts from Wilmington and runs over the high grounds on the west side of the Brandywine, entering the valley of that stream ten miles from Wilmington, at Twaddle's Ford, and follows the west branch of the Brandywine through Coatesville, and crossing over the East Brandywine near Isabella Furnace, thence by Springfield and Jones's Mines down the valley of Hay Creek to the Philadelphia and Reading Railroad, at Birdsboro'. The length of the road will be fifty-five miles, and estimated cost $1,664,000.

Mechanics, Physics and Chemistry.

LECTURE-NOTES ON PHYSICS.

By Prof. Alfred M. Mayer, Ph.D.

(Continued from vol. liv., page 329.)

§ II. *Instruments used in Precise Measurements.*

A law of Physics, as we have seen, consists in the general relation which exists between the numbers which are the final results of our observations and experiments; and therefore, the first subject to be discussed in the exposition of that process by which we arrive at a law, is the description of those *instruments* which have given such minute precision in the numerical determinations of modern Physicists.

The *instruments of precision* used in making the measures required by the Physicist may be arranged under the five following divisions:—

1. Instruments used to measure . . *Lengths.*
2. " " " . . *Angles.*
3. " " " . . *Volumes.*
4. " " " . . *Weight.*
5. " " " . . *Time.*

Instruments used to measure Lengths—Dividing Engines.

Standards of Length. Before commencing a measurement of length, the error of the unit we use should be accurately determined by comparison with a government standard, or with a well authenticated copy.

Two units of length are used in this country: *the yard* (subdivided into feet, inches, and tenths of inches), and *the mêtre* (subdivided into tenths, hundredths, thousandths, and so on decimally).

The yard, originally derived about 1120, from the length of King Henry the First's arm, was accurately *fixed* by Captain Kater, in 1818, when he obtained the ratio of the length of the *standard English yard* to the length of a pendulum beating seconds (*i. e.* making 86,400 vibrations in one mean *solar* day) *in vacuo* at the level of the sea, in the latitude of Greenwich. He found that the length of such a pendulum, from the point of suspension to the centre of oscillation, was 39·13929 inches.

The actual standard of length of the United States is a brass scale of 82 inches in length, prepared for the U. S. Coast Survey, by Troughton of London; meant to be identical with the English Imperial Standard, and deposited in the Office of Weights and Measures at Washington. The temperature at which it is a standard is 62° Fahr., and the yard measure is the length between the 27th and the 63d inches of the scale. (See "Report on the Construction and Distribution of Weights and Measures," by Dr. A. D. Bache. 1857.)

Two copies of the new British standard, viz: a bronze standard, No. 11, and a malleable iron standard, No. 57, have been presented by the British Government to the United States. A series of careful comparisons, made in 1856, by Mr. Saxton, under the direction of Dr. Bache, of the British bronze standard, No. 11, with the Troughton scale of 82 inches, showed that *the British bronze standard yard is shorter than the American yard by* 0·00087 *inch.* So that, in very exact measures with the yard-unit, it is necessary to state whether the standard is of England or of the United States.

"*The Mêtre* is a standard bar of platina, made by Lenoir in Paris, which has its normal length at the temperature of zero centigrade, or the freezing point. Its length is intended to make it a *natural* standard, and to represent *the ten millionth part* of the terrestrial arc comprised between the equator and the pole, or of a quarter of the meridian. The length of this arc, given by the measurement, ordered for the purpose by the Assemblée Nationale, of the arc of the meridian between Barcelona, through France to Dunkirk (about $9\frac{1}{2}$ degrees), combined with the measurements previously made in Peru and Lapland, gave for the distance of the equator from the pole 5,130,740 *toises.* The standard toise was made in 1735, in Paris, by Langlois, under the direction of Godin. It is a bar of iron which has its standard of length at the temperature of 13° Reaumur. It is known as the Toise du Pérou, because it was used by the French academicians Bouguer and La Condamine in their measurement of an arc of the meridian of Peru. The toise of Peru = 2·13145 English standard yards. They found an ellipticity of $\frac{1}{3\,1\,4}$, and the length of the mêtre 443·29596 lines of the toise du Pérou, assumed to be 443·296 lines or 3 feet 11·296 lines. This last quantity was declared in 1799 to be the length of the *legal mêtre*, and *vrai et définitif*, and is the length of Lenoir's platina standard. Later and more extensive measurements in various parts of the globe, however, seem to indicate that this quantity is somewhat too small. The latest and most exact

results we now possess, combined and computed by Bessel, would make the quarter of the meridian 10,000,856 mêtres, and the mêtre =443·29979 Paris lines. Schmidt's computation would make it 443·29977 lines, and both numbers are confirmed by Airy's results. The legal mêtre is thus, in fact, as Dove remarks, *a legalized part of the toise du Pérou*, and this last remains the *primitive standard*. But it must be added that a natural standard, in the absolute sense of the word, is a utopian one, which ever-changing nature never will give us. The mêtre is, for all practical purposes, what it was intended to be, a natural standard; though it must be confessed that, in practice, the question is not whether and how far a standard is a natural or a conventional one, but how readily accurately it can be obtained, or recovered when lost." (See A. Guyot's Tables, Meteorological and Physical, p. 111.) Captain Kater in 1818 determined with great care the value of the *mêtre* at a temperature of 32° Fahr., in inches of Shuckburgh's copy of the standard yard (made by Troughton) at 62° Fahr., and found one mêtre at 32° Fahr.; =39·37079 inches at 62° Fahr. Therefore the quadrant of the *French* meridian contains 393,707,900 English standard inches.

It has recently been shown by M. Schubert that the equator of the earth is not a great circle, but an ellipse; having its major axis =41,854,800 feet, and its minor axis=41,850,007 feet, giving an ellipticity of $\frac{1}{8880}$th. From this it necessarily follows that different quadrants of the earth will differ, being longer when passing near the major axis than when passing in the neighborhood of the minor axis. Consequently, the mêtre is only the $\frac{1}{10000000}$th part of the quadrant passing through Dunkirk. Sir John Herschel computes 4008 feet for the excess of the true quadrant over that assumed as the basis of the metrical system; which makes the French standard $\frac{1}{2058}$th of an inch too short.

Sir John Herschel proposes for the British standard an aliquot part of the *polar axis* of the earth, as a natural unit, and shows that by increasing the existing British standard yard (and with it of course its subdivisions) by exactly the $\frac{1}{10000}$th part of its present length, the polar axis will contain 500,500,000 of inches each $\frac{1}{10000}$th longer than the present standard inch. Herschel also shows, that by adopting this new value of a foot, that one cubic foot of distilled water at 62° Fahr. will contain 1000 ounces if we increase the present ounce only the $\frac{1}{18}$th of a grain; and thus there will exist a simple relation between the measures of length and of weight. (See Familiar

Lectures on Scientific Subjects, Article, "The Yard, Pendulum, and Mêtre," by Sir John Herschel. A. Strahan: London and New York, 1866.)

In 1866, Congress passed an act directing that 15 grammes of the metric system of weights shall be deemed, and be taken for U. S. postal purposes, as the equivalent of one-half ounce avoirdupois.

The new U. S. five-cent piece is made 2 centimetres in diameter, and weighs 5 grammes.

See plate I. for the French measure of one decimetre, divided into centimetres and millimetres; and the English measure of four inches divided into halves and tenths.

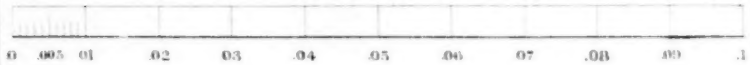
(The standards of one yard and of one mêtre exhibited.)

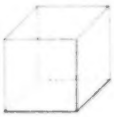
Measurement of lines of considerable length. There are two modes of directly measuring lines of considerable length. The first consists in placing in *contact* the ends of rods having an exact standard length, and thus applying these units to the line whose length is required. The second consists in bringing the beginning of one unit to coincide with the end of another, by *bisecting* a fine × mark near the end of one of the rods by the cross-threads in a microscope attached to the end of the other rod. The distance on a rod between the cross-hairs in the microscope at one end and the × mark at the other being equal to a standard length.

With the precise apparatus of the U. S. Coast Survey, a base of ten miles can be measured so accurately that the error made is only about $\pm \frac{1}{10}$th of an inch. (See U. S. Coast Survey Report for 1854, p. 103, *et seq.*, for a description of this apparatus for measuring base-lines.)

The Vernier is a device for subdividing still further the lowest divisions of a scale without dividing directly those divisions by equidistant lines. It consists of a *sliding* scale called the *vernier*, which glides along the length of the main scale, and has on it divisions which *differ* from those of the main scale by a known fraction of the smallest subdivision on the main scale. Thus, suppose we have a main scale of inches divided into tenths, and we wish to divide the tenths of inches into ten parts by a vernier, thus giving us the hundredths of inches: we take a length of *nine-tenths* from the main scale, and place it on the vernier, and we divide this length into *ten* equal parts, which necessarily gives divisions on the vernier, each of which is $\frac{1}{100}$th of an inch less than the smallest division of tenths on the main scale; therefore, by seeing where a line of the vernier corresponds with a

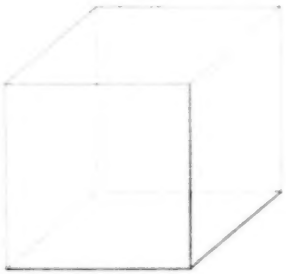
ONE DECIMÊTRE





One Cubic Centimêtre of Distilled Water at 4° C=1 Gramme.

FOUR INCHES



One Cubic Inch of Water at 62° F=252 456 Grains.

line on the main scale, the next following lines of the two scales are distant from each other $\frac{1}{100}$th of an inch; the next following lines differ $\frac{2}{100}$ths, and so on; and thus we can subdivide any $\frac{1}{10}$th of an inch of the main scale into hundredths of an inch.

In general, to read to the nth part of a scale division, n divisions of the vernier must equal $n + 1$ or $n - 1$ divisions on the main scale, according as these run in opposite or in similar directions.

Large models exhibited of vernier applied to straight line and to arcs of circles.

Rule for finding the smallest reading by means of the vernier. *Divide the value of the smallest divisions on the main scale by the number of divisions on the vernier.*

This beautiful and very useful invention is due to Pierre Vernier, of France, who first described it in a work entitled "La construction, l' usage et les propriétés du cadran nouveau." Bruxelles, 1631.

The Cathetometer (from Gr. Κάθετος vertical height, and μέτρον a measure), consists of a vertical rod, which rotates round its axis, and carries a telescope, provided with a spirit-level, whose line of collimation is at right-angles to the axis of the rod. The rod rests on a base furnished with levelling screws and spirit-levels, so that it can be brought into a truly vertical position. The telescope is attached to a vernier plate, which slides along the length of the rod which is divided into fractions of the mêtre or of the foot. The instrument is used to measure the vertical distance between two points, whether on the same vertical line or not. It is of constant use in making all measures of vertical distances.

(Instrument exhibited, and method of using it shown.)

This instrument was invented by Dulong and Petit, and subsequently improved by Pouillet.

Micrometer Screw (from Gr. μικρος small, and μέτρον a measure) consists of a screw with a large circular head, whose circumference is divided into a certain number of equal parts. Suppose the screw has 50 threads to the inch, and that its circular plate, which rotates with it, is divided into 200 parts; then if the screw is turned a whole revolution, it will advance, in the block in which it turns, $\frac{1}{50}$th of an inch; but if the head is revolved only through $\frac{1}{200}$th of a revolution, the screw will advance the $\frac{1}{10000}$th of an inch. With a good micrometer screw we can measure accurately the $\frac{1}{1000}$th of a millimetre, or about the $\frac{4}{10000}$th of an inch.

(Large model exhibited, also the instrument itself in various forms.)

Spherometer. As its name indicates, it is used to measure spheres; or, more concisely, to determine the radius of any spherical surface, as, for instance, the radius of the surface of a glass lens. It was invented by the optician de Laroue, for the latter determination. It consists in a micrometer screw, supported vertically by a tripod. The points of the feet of the tripod are equally distant from each other; and they, as well as the screw, terminate in fine nicely rounded extremities. The point of the screw and the points of the tripod are brought into the same plane by placing the instrument on the truly plane surface of a slightly roughened glass plate, and bringing the screw's point to bear on the plane with the same degree of pressure as the points of the tripod. This is attained by means of a jointed lever, which moves with the screw, and its shorter arm bearing on the glass, its longer arm is always brought into the same position. This can only be clearly understood by examining the instrument. The instrument is now removed to the lens, the radius of whose curvature we desire, and the point of the screw brought down upon the glass till it bears with the same degree of pressure as in the previous instance. The difference of readings on the head of the micrometer screw gives the perpendicular distance of the point of the screw above the plane passing through the points of the feet of the tripod; or, in other words, the height of a segment of a sphere, having for radius the radius of curvature of the lens, and for base the circumscribed circle of the equilateral triangle made by the points of the three feet of the spherometer.

Calling this height h, the radius of the circle passing through the feet of the tripod r, and the radius of the spherical surface of the lens R, we have

$$2\,R - h : r :: r : h; \quad \text{whence}$$
$$2\,R\,h - h^2 = r^2; \quad \text{therefore}$$
$$2\,R = \frac{r^2 + h^2}{h},$$

half the value of 2 R being of course the radius of curvature of the lens.

The spherometer will give accurate measures to the $\frac{1}{1000}$th of a millimetre, and is so minute in its measurements, that if the finger be momentarily placed on the plate of glass under the point of the screw, and we again bring down the screw to this portion of the glass, we find that the heat from the finger has swelled the glass at the part touched into a protuberance!

It is easy to see how this instrument is also used for measuring the thickness of plates.

Comparator. Model of instrument exhibited and described. Invented by Lenoir in 1800, to compare standards of length.

In this instrument, as well as in the following one, we measure a multiple of the quantity we wish to estimate.

Saxton's Reflecting Comparator and Pyrometer. Model of this instrument exhibited, and mode of using it shown.

It is so delicate that it will measure with precision the $\frac{1}{100000}$th of an inch.

"This very ingenious instrument has been applied to comparing the yard of the kind called *end-measure*, in which the distance between the two ends of the bar is the length of the standard yard. One end of the bar to be compared abuts against a fixed support, the other end is free to move, the whole bar being supported horizontally on rollers. The free end presses against a small horizontal bar or slide, connected by a chain, with a vertical axis, carrying a small mirror. As the free end of the bar moves, the slide moves also, and turns the mirror. A scale placed horizontally at any convenient distance from the bar and in the same general direction, is reflected in the mirror, the image being viewed by a telescope placed at the same distance as the scale, and directly over it. The distance of the reflected image of the scale being twice that of the scale from the mirror, the motion of the mirror is shown as on a divided circle of that radius, and the smallest movement of the mirror is measurable."

(See "Report by Dr. A. D. Bache, to the Secretary of the Treasury, on the Construction and Distribution of Weights and Measures," Washington, 1857, p. 15, *et seq.*)

The illustrious Gauss, of Göttingen, first used this method of reflection in his measures of the forces of terrestrial magnetism.

It also can be applied to the galvanometer, by attaching its needles to a very light silvered mirror; and thus the smallest motions of the needles can be shown to the largest audience.

Dividing Engines. To divide the straight line into fractional parts, and the circumference of the circle into degrees, minutes, and seconds, machines are used which, when made with care and used with skill, are capable of working with great precision.

To divide the straight line. The simplest apparatus for dividing the straight line is that described by Bunsen in his "Gasometry" (London, 1857). The rod, tube, &c., to be divided is placed in a

line with a standard scale, and with long, rigid beam-dividers, having one of its points on a division of the scale we describe, with the other point a line on the rod &c. to be divided; we then move the point of the dividers to the next division of the scale, describe with the other point another line on the rod, and so on.

If the weight of the dividers is partly supported by a cord, passing over a pulley overhead, and attached to a weight, and an assistant, with a glass, carefully places the point on a division of the scale while the operator describes the line, this method will give an accurate copy of the scale from which we transfer the divisions.

The most accurate machine for dividing the straight line consists of a plate placed on Λ shaped guides, and moved in the direction of its length by a screw attached to its lower side. The rod &c. to be divided is clamped to the upper surface of the plate, and a cutting tool, which can only move in one and the same plane perpendicular to the length of the plate, cuts the divisions on the rod after each rotation of the screw. If the screw contains ten threads to the centimetre, then at each whole revolution of the screw the plate will advance one millimetre; and any fraction of a millimetre can be cut by rotating the screw that same fraction of a whole revolution.

So minute is the accuracy of which this machine is susceptible, that it is able to cut 75,000 equidistant and parallel lines in the breadth of an inch, and each division is distinctly visible under the highest power of the microscope. A still greater number, probably over 100,000 lines, can be cut in the length of an inch, but they cannot be discerned even by the highest powers of the best microscopes, furnished with the most perfect means of illumination. In this case our mechanical exceeds our optical power.

A graduated series of these lines, increasing in the number to the inch, are used under the name of Nobert's test lines, to determine the defining power of the objectives of microscopes.

Another example of fine engine work is given in "Barton's buttons," which are gold buttons stamped with a hard steel die on which Barton cut hexagonal groups of fine equidistant lines with a diamond. On account of the interference produced in the light reflected from the surface of these buttons, they flash with the brilliancy and the colors of gems.

From the above description of the performance of the dividing engine, it is easy to see how, having fine lines cut at known intervals apart on plates of glass, and placed in the ocular or on the

stage of a microscope, we have the means of measuring distances which surpass in minuteness the determinations of the micrometer-screw.

To divide the circumference of the circle. Two methods are used in the graduation of the circumferences of the circles of astronomical and other instruments.

In the first, and probably the most accurate method, the circle to be divided is centered and clamped upon a large *accurately* graduated circular plate, which revolves on a vertical axis, and under a cutting tool which moves only in one and the same vertical plane passing through the centre of the circle. The divisions on the periphery of the large and *originally divided* circle are successively bisected by the cross-wires in the ocular of a fixed microscope, by revolving the plate under the microscope by means of a tangent screw; and at each bisection the tool cuts a line in the border of the circle to be graduated.

In the other method a tangent screw works in the notched edge of a circular plate; and by one whole revolution of the screw the plate is carried round 10′. After each revolution the tool cuts the division. Thus the circle is divided into arcs of 10′ and into smaller fractions of a degree if desired.

The first method is used in Germany; the second, invented by Ramsden, and subsequently improved by Troughton & Sims, and by Gambey, of Paris, is practiced in England and in this country. At the U. S. Coast Survey Office in Washington, can be seen a very superior dividing engine, made by Troughton & Sims, of London.

In both methods the circle of the engine has originally to be divided by the principle of bisection. To bisect a straight line, one point of a beam-compass is placed at one extremity of the line, while with the other point we strike a fine line nearly bisecting the line we wish to divide. From the other extremity of the line an arc is struck with the same radius, and the minute space included between the lines thus formed is bisected with a fine needle-point under a microscope. A scale of equal parts is thus formed with the most extreme care; and having attached to it an accurate vernier, we take in the beam-compass from this scale a length which exactly equals the chord of an arc of 85° 20′ of the circle to be graduated, and with this chord we strike on the circle an arc of 85° 20′. By continued bisections this arc is subdivided into equal parts of 5′ each. The 60° division can be obtained by a chord equal to the radius of the

circle, and this arc of 60° bisected gives 30°, which, added to previous arc of 60°, gives an arc of 90°.

The reader is referred to an article on "Graduation," by the celebrated artist Troughton, in the *Edinburgh Encyclopedia*, for the best account extant of this, the most delicate and difficult problem of mechanical art; which has tested to the utmost the combined skill of the first mechanicians, and of the ablest astronomers of modern times.

(To be continued.)

MANUFACTURE OF BEET-ROOT SUGAR IN THE UNITED STATES.

By John Birkbeck.

Feeling a deep interest in all that relates to the successful progress of American industry, the writer was induced, during a late trip to the West, to make a visit to the Beet-root plantation and sugar manufactory established at Chatsworth, Illinois.

Chatsworth is a village of some 800 inhabitants, located in Livingston County, on the line of the Toledo, Peoria and Warsaw Railway. The direction of this railway is east and west, connecting at Gilman, fifteen miles east of Chatsworth, with the Chicago branch of the Illinois Central Railway, at Chenoa, twenty-two miles west, with the Chicago, St. Louis and Alton Railway, and at El Passo, thirty-seven miles west, with the main line of the Illinois Central Railway.

This location is on the prairie land; the marked feature of the country being its level surface, unbroken by either hills or trees of any size. The greater part of the land is uncultivated, and is covered with prairie grass.

The plantation and works of the Germania Sugar Co. are located at the south-east corner of the village. They have 2500 acres of land, 550 of which have been planted this year with the sugar-beet, and the balance with corn, oats and hay.

The refinery is located near the railway track, and consists of main buildings of wood, which contain the machinery proper, and several other frame buildings, used as storehouses and stables.

The enterprise was started some four years since by the brothers Gennert of New York, but has since been made a stock company, the members of which are all residents of the West.

The planting is done in April, and the beets harvested in Octo-

ber, at which time the manufacturing commences, and continues until March. On harvesting, the beets are piled in trenches in the fields for protection from the frosts, enough being taken each day to supply the working capacity of the refinery. The machinery was transported from Germany, and has a capacity for working sixty tons of beets in twenty-four hours.

The first process is the washing of the beets, and for that purpose is used a cylindrical vessel four feet diameter by ten feet long, its circumference or shell made of wooden slats placed longitudinally, with alternate openings between them. This drum is placed at an angle of 10°, both ends are open, the beets thrown into the higher end, and the drum slowly revolved by appropriate gearing in a water-tank of sufficient depth to bring the water-line midway between the axis and lower edge of drum. The interior of the drum is provided with a spiral screw and angle-pieces, which give the beets a continual movement through the water towards the lower end, the earthy matter being washed off and passing through the openings between the slats into the tank below. The beets are discharged from the lower end on a revolving table some twelve feet in diameter, around which are placed women and boys, who remove all the diseased and defective ones, and prune off all the useless parts. The perfect beets are thrown into the buckets of an elevator near at hand, and discharged into a hopper on the floor above, which delivers them to two rasping or pulping machines. These machines are simple, and consist of revolving drums about two feet diameter by two feet long, the circumference being provided with projecting saw-blades set at a slight angle with their axis, the blades being parallel with each other, and about two inches apart. The drums are revolved with great rapidity inside of close cases, and water to the amount of ten per cent. of the weight of the beets is introduced continuously during the operation. The discharge is a fine pulp, delivered into a traveling bucket, in front of ten centrifugal draining machines, which are placed on an intermediate floor midway between the first and second floors.

The charge for each centrifugal is 200 pounds of pulp, in which twenty pounds of water has been added during the rasping process, making 220 pounds in all. The centrifugal drum is then revolved some 1500 revolutions per minute, thirty-five per cent. additional water being introduced during the process.

The juice evolved in the operation is conducted from the centrifu-

gals by canals to a line of six deficators, each of 300 gallons capacity, while the dry pulp is removed from the interior of the drum for the use of the cattle as fodder.

The deficating process is the same as pursued with sugar cane juice, excepting that an excessive quantity of lime is used for neutralizing the acids.

Below each deficator is an upright cylindrical vessel made of wrought iron plate, of about 600 gallons capacity. These vessels are provided with heating worms at their bottoms, and covers with hinges on top. The clear juice of each deficator is discharged into the corresponding vessel below it.

The scum arising from the defication is subjected to the action of scum presses, by which the syrup remaining is made available.

The lime employed in the defication is removed by the action of carbonic acid gas, which is forced into the liquor while in the vessels below the deficators, by means of a steam-pump. The gas is manufactured in a lime kiln, on the premises.

On admitting the gas into the juice, the latter froths very much, which accounts for the necessity of having the receiving vessels of double the capacity of the deficators.

On the decomposition of the lime, the supply of gas is stopped; the liquor is then heated to the boiling point, and by means of a monte-jus elevated to a tank above the filters.

The deposit in the vessels, after the drawing of the liquor, is also subject to the action of the scum presses.

The filters are six in number, and of the bone-black variety, about thirty inches in diameter, by thirty feet high. Three of them are used for the first filtration. After leaving these filters, the liquor is carried to a series of three evaporaters. They are plate-iron vessels about eight feet diameter, by three feet deep, provided with a copper coil or worm at their bottoms. Steam is admitted into the coils, and the liquor concentrated to about 26° B; the scum arising during the boiling is also subjected to the action of the presses.

From the evaporaters, the juice is elevated by a second monte-jus to a tank above the second set of filters, and after this second filtration, passes to a vacuum pan, and is boiled down to the crystallizing point. Five centrifugal machines are employed for the purging operation. The sugar discharged from the vacuum pan is carried to a mixer, located on the floor above the five centrifugals; the mixer

discharges into a traveling bucket arranged for supplying all the centrifugals.

The first product of this operation is a beautiful white sugar of heavy grain, ready for the drying tables and the market. The syrup evolved during this operation is re-boiled in the vacuum pan, and re-worked in the centrifugals, making a fair brown sugar.

The refinery is supplied with the ordinary washers and ovens for re-washing and revivifying the bone-black.

Steam is supplied by four forty-inch by thirty-feet double flue boilers, and two sixty-inch by thirty-feet boilers, the two latter each containing five flues. The fuel used is coal; it is not of very good quality, but is to be had in abundance, one shaft being worked in the village. The price is about ten cents per bushel.

This, like most new enterprises, has met with its discouragements.

The first attempt at sugar making on a large scale, was made during the autumn of 1866 and winter of 1867. Some of the machinery proved defective, and it was found impossible to obtain the requisite steam on account of deficiency of boiler power, and the want of a proper smoke-stack.

The beet crop was an abundant one, averaging some fifteen tons per acre, and would have required four and half months working of the refinery to manufacture into sugar, at an average of sixty tons per day; owing to the defects mentioned, not near this quantity was reached, and as a consequence, tons of beets had to be carted and thrown away to make room for the spring planting.

Although the enterprise proved a failure in a pecuniary point of view, yet the cause was plainly seen to have been a remediable mechanical one.

The product per acre proved the land to be well adapted to the culture of the beet, while the operation of the refinery, giving eight per cent. of sugar, compares favorably with the best results in Europe.

During the past summer, additional boiler power was placed and other defects remedied, and those interested had every reason to hope that this present season would give a rich reward for all the energy, perseverance, and patience they had displayed.

Unfortunately, this will not be the case, as this last has been the dryest season experienced in the West for a period of thirty years. No rain of any consequence has fallen since June, and the beet crop has proved a failure. It has been gathered, and gives an average

of only three tons per acre, instead of fifteen, as on the previous year.

The season has been an exceptional one in Illinois, and the effects of the drought have been very serious. Most of the wells have failed, cattle have been and are dying from thirst, and the Illinois Central Railroad is carrying water from Chicago down their road for the use of their locomotives. Such a season may not again be experienced for many years.

Notwithstanding these discouragements, there can be no doubt of the final success of the enterprise.

Persons who have lived in the State some twenty years, and are familiar with its characteristics, assert, that good crops of beets can be had at least nine years out of ten.

The Messrs. Gennert have proved the feasibility of extracting the sugar in such quantities that there will be left a good margin of profit. They are the pioneers in this country of an enterprise which will eventually prove one of the most important elements of public prosperity.

The enterprise can be carried on profitably in nearly all of our Northern States,—those which can offer the advantages of cheap land, cheap labor, coal, lime, water, and a ready market are of course to be preferred.

As there can be no doubt in regard to our possession of the above facilities, then the only question to ask is, have we the engineering and mechanical skill to design and construct the proper machinery for the manipulation of beet root into sugar, and the enterprise to engage in and carry forward the project to a successful result?

In regard to the machinery, the question can be satisfactorily answered.

Nearly all the parts required are precisely similar to those manufactured in this city during the past twenty-four years for Louisiana, Cuba, and South America, for making sugar from cane juice, the only difference being in the pieces used for extracting the cane juice and beet juice, respectively. At Chatsworth, the evaporating is done in open kettles, which is an expensive mode so far as fuel is concerned, and is also destructive to the color of the liquor.

In Germany, in the best refineries, vacuum pans of treble effect are used for evaporating, three being generally employed.

They are placed near each other on one common platform, the first being worked by the exhaust steam of the different steam

engines in the refinery, the second by the vapors of the boiling liquor of the first, and the third, or strike pan, by the vapors of the second.

The economy of this plan is self-evident, while the low temperatures required for boiling, as well as the absence of exposure of the liquor to the atmosphere, prevents the deleterious effects noticed by the use of open kettles. This system had its origin in this country, and has been most successfully practised for many years in Louisiana, Cuba, and South America, in the evaporation of cane juice.

The enterprising spirit required surely cannot be wanting. There has never been a lack of it in this country, and I feel sanguine that many years will not elapse, before all the sugar consumed in the country will be of domestic growth and manufacture.

The importance of getting all the saccharine matter from the raw beet, has resulted in many devices for its extraction. In Europe are employed for that purpose, hydraulic presses, centrifugals, cold maceration, and what is called the "*Diffusion Process.*"

The centrifugal process has been considered as best adapted for the purpose in this country, requiring but little labor in working, while the per centage of juice has been good as compared with the other modes.

A beet-root plantation and refinery is about being started at Aurora, near Chicago, Illinois, and is to be worked on the diffusion principal.

Those interested claim a gain of 1¼ to 1½ per cent. of sugar over every other mode, with less labor, and that the refuse or pulp is better as food for cattle.

European capital will be employed in this enterprise, and as Congress has exempted from duty all machinery needed in the manufacture of beet sugar, the major portion will be imported, while our own steam-engine and machine establishments, capable of doing the whole work, are suffering for want of orders.

In a future article will be given the details of the various processes employed for extracting the juice from the raw beet.

FLAME REACTIONS.

By Professor Bunsen.

Translated by Prof. Charles F. Himes, Ph.D., Dickinson College, Carlisle, Pa.

(Continued from vol. liv., page 334.)

2. *The fusibility* is determined according to the six grades of temperature before given. During the heating at increasing tempera-

tures, it must be noticed with the lens, whether the specimen decreases in size or puffs up, whether it gives off bubbles at or above the temperature of fusion, whether it is transparent after cooling, and what changes of color it suffers during or after its treatment in the flame.

3. *The volatility* is tested by volatilizing beads of the substance, of equal weight, upon platinum wire in the zone of fusion, and measuring thereby, in the simplest way, by means of a metronome, the time required for the volatilization. The instant at which it is completed can be recognized with a great degree of exactness, often even to the fraction of a second, by the sudden disappearance of the coloration of the flame. The platinum wire on which the bead is treated is protected during the weighing from atmospheric moisture in a test tube, Fig. 7. If the wire with the enclosing test tube is weighed once for all, and the weight of the bead to be volatilized added to it, the weighing off of the beads can be accomplished very rapidly by rendering them lighter or heavier, as may be necessary, by volatilizing a portion, or by fusing more of the substance on to it. The tests are best made with beads weighing about a centigramme. The portion of the zone of fusion in which the highest temperature, constant during the time required for comparative tests, prevails, is ascertained by moving a fine platinum wire placed upon the arm *a*, Fig. 5, with its end bent downward at a right-angle, slowly back and forth through the zone of fusion, and fixing it at the point where it glows most intensely. The beads to be volatilized must always be most carefully placed the same distance below the point of this wire. It must be noticed in this connection, whether the size of the flame does not change materially during the experiments, by reason of irregularity of pressure upon the gas. As unit of volatility, it is most convenient to adopt the time required to volatilize one centigramme of chloride of sodium. If this time be represented by t_0, and the time required for an equal weight of another substance by t_1, the volatility of the latter, compared with that of chloride of sodium, will be $v = \frac{t_0}{t_1}$.

Fig. 7.

To the annexed examples, from experiments by Dr. Hurtzig, I have added those of chlorides of rubidium and caesium.

I cannot omit to state that the relation between these numbers

does not change inconsiderably when the temperature of volatilization and weight of the substance volatilized are different. It is so much the more striking, that an approximate relation should manifest itself between the volatility and atomic weight of the more easily volatilized, analogously constituted substances of the table,

	Time of Volatilization.	Volatility.
Chloride of sodium	84·25	1·000
Sulphate of soda	1267·0	0·066
Carbonate of lithia	736·5	0·114
Sulphate of potassa	665·2	0·127
Carbonate of soda	632·0	0·133
Carbonate of potassa	272·0	0·310
Chloride of lithium	114·0	0·739
Chloride of potassium	65·4	1·288
Bromide of sodium	48·8	1·727
Bromide of potassium	41·0	2·055
Chloride of rubidium	38·6	2·183
Iodide of sodium	35·7	2·360
Chloride of caesium	31·3	2·717
Iodide of potassium	29·8	2·828

which can scarcely be ascribed to accident. Thus the following numbers show that with those haloid compounds, which volatilize without a residue, the volatility increases directly as the atomic weight. Representing the atomic weights by A, and the volatility by V, $\frac{V}{A}$ will be found to be practically nearly constant.

	A	V	$\frac{V}{A}$
Chloride of lithium	42·49	0·739	·0174
Chloride of sodium	58·43	1·000	·0171
Chloride of potassium	74·57	1·288	·0173
Bromide of sodium	102·97	1·727	·0168
Bromide of potassium	119·11	2·055	·0173
Chloride of rubidium	120·82	2·183	·0181
Iodide of sodium	150·07	2·360	·0157
Chloride of caesium	168·46	2·717	·0161
Iodide of potassium	166·21	2·828	·0170

Drops of water, alcohol, ether, and other easily volatilized substances brought into the flame upon platinum wire, do not boil, even in the hottest portion of the zone of fusion, and manifest, therefore, under these circumstances, the phenomenon of Leidenfrost's experiment.

4. *Coloration of the flame.* Many substances volatilized in the flame can be recognized by the peculiar kind of light which they emit as incandescent gases. These colorations appear in the upper oxydizing flame, if the substances producing them be placed in the upper reducing flame. Mixtures of substances producing different colorations of the flame are tested in the coldest portion of the base of the flame, at which place it is often possible to obtain, for an instant, the coloration produced by the more volatile, unmixed with that of the more difficultly volatilizable.

B. *Oxidation and Reduction of Substances.*

The following methods are employed to detect substances by the appearances which they present upon oxidation or reduction, and to accomplish their separation in a form adapted to further testing.

1. *Reduction in small glass tubes.* This is employed more especially for the detection of mercury, or for the separation of sulphur, selenium, phosphorus, &c., in combination with sodium or magnesium. A supply of tubes of very thin glass, 2–3 millimetres wide, and about 3 centimetres long, should be prepared. About forty can be made out of a common test tube of thin glass, of the size of the thumb, by heating it uniformly in the lamp-flame until the glass becomes soft, then drawing it out slowly into long tubes of the required diameter, and breaking them by scratching them with a writing diamond, into tubes 6–8 centimetres long, and after drawing these out in the middle, fusing the part drawn out round. The test specimen, after being crushed to a fine powder on the lamp-plate, Fig. 3, with the steel blade *a*, Fig. 4, is treated in the tube either with charcoal and carbonate of soda, or with sodium, or magnesium alone. In the latter case, a piece of moderately thick magnesium wire, several millimetres long, is used, which is stuck into the substance placed in the glass tube. Sodium must be carefully freed from naphtha by means of blotting paper, and rolled between the fingers into a small cylinder, which is to be surrounded with the substance in the glass tube. The soot from oil of turpentine deposited on a porcelain capsule filled with cold water serves best as charcoal. After the tube containing the previously perfectly dried test specimen has been heated to the point of fusion of the glass, when the contents will usually be seen to glow, it is crushed when cold under a piece of paper with the steel blade upon the lamp-plate, in order to test the products of reduction further.

2. *Reduction on a small charcoal rod.* This affords the metals, fused to globules, or as spongy masses, and can often be carried out with certainty even with a particle of the substance weighing less than a milligramme.

A crystal of carbonate of soda, which has not effloresced, is brought near the side of the flame, and a common match, coated three-quarters of its length with the pasty drops, formed. If it is then slowly revolved in the flame, a crust of solid carbonate of soda will form around the charred wood, which, upon heating in the zone of fusion, melts, and is absorbed by the charcoal. In this way a small rod of charcoal is obtained, which is protected from ready combustion by its soda glaze. A portion of the substance to be tested, about the size of a millet seed, mixed by means of the knife, Fig. 4, upon the hand with a drop of the melted soda crystal to a pasty mass, is placed upon the end of the charcoal rod. After it has been fused in the lower oxidizing flame, it is passed through a part of the dark nucleus into the opposite hottest portion of the lower reducing flame. The period at which the reduction takes place can be recognized by the active effervescence of the soda, which after a few moments is checked by allowing the test specimen on the charcoal rod to cool in the dark nucleus. In order to isolate the separated metal, the end of the charcoal containing the test specimen is pinched off with the fingers, and rubbed with a few drops of water in a small, smooth agate mortar, when the metallic spangles will in most cases be clearly seen, without further washing by decantation. These metallic spangles can easily be freed from carbon and carbonate of soda, for further testing, by repeated careful decantation, and then rinsing on a flat piece of glass, best broken from an old chemical flask *of thin glass*,* and, after pouring off and soaking up the water by means of blotting paper, they can be obtained dry by warming moderately. Several tenths of a milligramme of the metal, isolated in this way, suffice, in most cases, for the preparation of a solution that will answer for all characteristic precipitations, if the reagents are drawn up into capillary glass tubes, and added by the milligramme, and the reactions that occur observed with aid of a lens. Iron, cobalt and nickel, which do not fuse to globules in the carbon rod, are drawn out of the mass, rubbed with water in an agate mortar, by means of the magnetic knife-blade, *b*, Fig. 4, rinsed with water on the knife-blade, and dried upon it high above

* Watch-glasses are too liable to crack to be used for such operations.

the flame. If the blade is now drawn between the upper joint of the thumb and the lower one of the front finger, tightly pressed together, and the magnetic blade then brought near to the metals which have been wiped off, they will be attracted from the hand to it, and form a tuft that can readily be investigated by means of a lens, and by touching with a melted borax bead can be transferred to it in such quantity as may be desired. The residue sticking to the knife is wiped off on a piece of blotting-paper, in order to dissolve it with a drop of acid, by warming the paper over the flame, to test it further with reagents.

3. *Deposits upon porcelain.* The volatile elements reducible by hydrogen and carbon can be separated as such, or as oxides, out of their compounds, and be obtained in the form of deposits upon porcelain. Such deposits are converted with extreme ease into iodides, sulphides, and other compounds, which afford very characteristic and valuable indications for the recognition of substances. The deposits consist of a thicker layer in the middle, which passes very gradually on all sides into a very delicate film. In order to distinguish these, the term *incrustation* is applied to the heavier part and *coating* to the lighter. Both exhibit, by reason of the very gradual transition, all gradations of color peculiar to the substances in different degrees of fine division. From ·1 to 1· milligramme of the substance suffices in many cases for these reactions. Many of them surpass in definiteness and accuracy Marsh's test for arsenic, and approximate in sensitiveness the spectral analysis.

(To be continued.)

METHOD OF QUALITATIVE ANALYSIS OF ANIMAL AND VEGETABLE COLORING MATTERS BY THE SPECTRUM MICROSCOPE.

By H. C. Sorby, F. R. S., &c.

(Continued from vol. liv., page 417.)

7. *Preparation of Colors.*

If the petals, leaves, &c., of plants be crushed in water, it very commonly happens that the color is rapidly decomposed and no clear solution can be obtained; but if crushed in a moderate quantity of spirits of wine, and the solution squeezed out, filtered and evaporated to dryness at a gentle heat, the coloring matter does not decompose, even when re-dissolved in water and filtered to remove anything not

soluble in that liquid. This clear solution should then be evaporated to dryness at a gentle heat in a small saucer, and kept *dry;* for then the colors often undergo no important change in the course of many months, whereas, when kept dissolved in water or alcohol, they may quickly decompose. I have thus prepared the coloring matter of above a hundred different vegetable substances, some of which have become entirely changed, but a large number are apparently still unaltered. I have also kept a number of colors, sealed up in glass tubes, ready for direct examination, dissolved in alcohol, in strong syrup or in alum. Many have decomposed, but many have kept perfectly well, or have merely faded, and still give excellent spectra after above a year. I have also prepared and kept in the same manner some animal coloring matters, but comparatively few.

8. *Method of Examination.*

The colored substances are examined, when dissolved in water, alcohol, or other solvent, in the small glass cells already described, and the various reagents are added and mixed by means of a moderately stout platinum wire, flattened at one end and turned up square like a little hoe. I have made many experiments in order to ascertain what reagents are most serviceable in developing characteristic spectra, and have at length concluded, that, for general purposes, the following are the most convenient. Those which are solid are best kept in small bottles as coarse powder, and added to the small cells in a solid state, so that the quantity used may be more readily known.

9. *Reagents.*

Hydrochloric acid.
Citric acid.
Benzoic acid.
Boracic acid.
Bicarbonate of ammonia.
Carbonate of soda.
Diluted solution of ammonia.
Caustic potash.
Sulphite of soda.
Sulphate of protoxide of iron.
Alum.
Iodine dissolved in alcohol.
Bromine dissolved in water.
Solution of hypochlorite of soda.
Permanganate of potash.

This list might, of course, be very much extended, if we were to include such reagents as may be used in separating or decomposing colors by the ordinary chemical methods. In describing the effect of those named in this list, I feel that I could not avoid mentioning

some well-known facts without breaking the thread of my argument; and therefore I trust it may not be thought out of place if I give a general account of the whole from the particular point of view required by the subject more especially before us.

The action of many reagents is so intimately related to different parts of the spectrum, as to show that there must be some connection between so-called chemical reactions and optical phenomena. Not that their effect is absolutely the same in the case of all colored substances, but generally only the *extent* differs, whilst the *character* of the change is uniform, unless, indeed, decomposition take place, and even then it has a tendency to conform to a general law.

10. *Solvents.*

Water and alcohol are the most useful solvents, and the spectra of the two solutions of the same substance often differ most strikingly; in fact, they often behave in other respects as if they were solutions of different substances. Sometimes the spectra are absolutely identical, but often well-marked narrow absorption bands are seen in the alcoholic solution, where they are almost or quite invisible in the aqueous. Very commonly the bands are seen in both, but not exactly in the same place, alcohol sometimes raising them to a higher part of the spectrum, and sometimes depressing them. Occasionally the spectrum of the dry material is like that of the alcoholic solution, and unlike that of the aqueous, as if the difference were due to the presence of water, but in other cases it is unlike both. At all events, the facts clearly show that a solvent has a most important action on the ultimate particles of the substance in solution, since it may produce a greater change in optical phenomena than even chemical combination. Undistilled hard water may act like a weak alkali.

11. *Acids and Alkalies.*

As far as optical phenomena are concerned, there is no absolute division between acids and alkalies; for we have every connecting link from the strongest acids to the strongest alkalies. In order to understand their action it is most essential to distinguish between what may be called "general absorption" and "local absorption bands." There may, perhaps, be no absolute line of division, but when seen to advantage they are affected in such a different manner that it is desirable to treat of each separately.

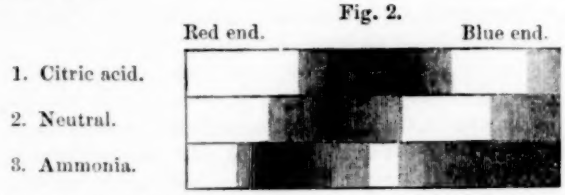
12. *General Absorption.*

As a good example of simple general absorption, we may take the crimson coloring matter of the common Wall flower (*Cheiranthus Cheiri*), which is soluble in water, and, along with a yellow only soluble in alcohol, gives rise to the varied colors of the flowers.

When neutral, it is crimson			$2\frac{3}{4}$	....	7		10.	.11-	—
With ammonia, fine green	$1\frac{1}{4}$	—	$4\frac{1}{2}$	..	6	7	..	8- .	9—
With citric acid deep pink			$3\frac{1}{2}$	..	$4\frac{1}{2}$	— 6-	..	$8\frac{1}{2}$	11...

The facts will be better understood by means of the following drawing:—

Fig. 2.



Whence it will be seen that citric acid raises and greatly increases the central absorption, and ammonia lowers and also increases it. At the same time, the absorption at the extreme blue end of the spectrum is raised by the acid almost to beyond the range of vision, but lowered to the centre of the spectrum by ammonia. Acids and alkalies of intermediate character, as for example, boracic acid and bicarbonate of ammonia, produce intermediate effects. These well-known phenomena may be looked upon as typical of acids and alkalies, but the extent of their action varies for each particular coloring matter, so that, in some cases, it is slight, and sometimes neither acids nor alkalies produce any effect. Their relative action on the central and upper absorption also varies very greatly in different colors. If there is no general absorption in the centre of the spectrum, when the color is neutral, but only an absorption at the blue end, acids and alkalies act on it in precisely the same manner as on the absorption at the blue end in the case just described, raising or lowering it to an extent varying greatly according to the substance; and the same may be said of any general absorption at the red end. The reverse certainly occurs when an acid is added to chromate of potash, or excess of ammonia to a salt of copper, and, according to Stokes (*Phil. Trans.*, 1862, p. 609), alkaloid bases usually show this reverse action. It may depend on the different properties of two distinct *compounds*, which does not appear to be the cause of the phenomena now under consideration. In the case of all the vegetable coloring matters which I have examined, the tendency of acids is to raise, and of alkalies to depress, the general absorption in each part of the spectrum; the extent of the action depending on the strength and quantity of the reagents, and on the nature of each coloring matter, and thus we have a general rule, and not several, as commonly adopted by chemists, each of very limited application; for instance, that vegetable blues are turned red by acids, and green by alkalies; and that vegetable yellows are reddened by alkalies. I may here remark, that some colors would appear to be exceptions, if we did not remember that waves of light,

or waves analogous to them, exist beyond the visible spectrum. Thus, for example, when alkalies are added to the yellow solution of Brazil wood (*Cæsalpinia crista*), it is changed to pink, the absorption being so much lowered that the blues are transmitted; this clear space corresponding to what was probably a clear space beyond the blues visible under ordinary circumstances, but which would perhaps be seen, if examined in the manner described by Stokes in his paper on the long spectrum of electric light.*

13. *Fading of Solutions.*

One striking peculiarity in the action of acids on the solutions of many vegetable colors is, that when they are in a particular state of acidity, they fade to nearly or quite colorless, without their being any decomposition. This is especially the case with pink colors dissolved in alcohol. It occurs slightly with blue colors, and little, if at all, with yellows. The aqueous solutions change much more slowly, but more and more rapidly the more they are diluted; and frequently attain a permanent depth of color, which is dark or pale according as the solution is strong or dilute. Of course, I here allude to the effect of the *same total amount of color*, and not to the different effect of the same *quantity* of a strong or dilute *solution*. The alcoholic solutions obtained direct from the flowers often fade so rapidly, and become so nearly colorless, that any one might easily fancy that all the color was lost by decomposition, and an evaporating dish containing it might appear merely filled with a brownish alcohol, and yet on evaporation the whole dish might be covered with a fine deep color. The same change may occur over and over again, the deep coloration first obtained soon fading, and the color being restored by subsequent evaporation.

When such a color is dissolved in a little water and added to alcohol in an experiment tube, the color may at first be very deep, but may fade so rapidly that there is scarcely time to observe the spectrum before it passes into that molecular state which does not absorb any of the rays of light. The coloring matter of the red Salvia (*S. splendens*) is an excellent example. Neutral solutions do not undergo this rapid change; a different condition of acidity is requisite for different coloring matters; and some do not change at all. A large excess of citric acid very often restores the intensity of the color; and usually the absorption bands are seen to the greatest advantage when the solution is in that state which rapidly fades; and by adding too much color and watching whilst it fades, they may be seen and measured when at their best. This fading of a dark-colored solution must not be confounded with the change which takes place on diluting some salts as described by Dr. Gladstone in his paper on that subject.†

* Phil. Trans., 1862, p. 599.

† Quart. Jour. Chem. Soc., vol. xi., p. 36.

14. *Absorption Bands.*

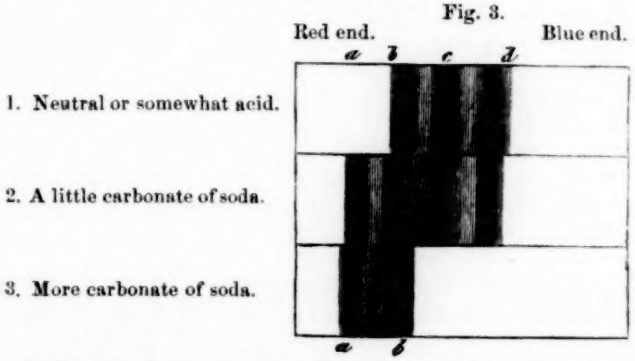
Though acids and alkalies thus, to a greater or less extent, alter the position of the general absorption, they act very differently on the special local absorption to which it is very convenient to restrict the term "absorption bands." Since I shall often have to speak of their being at equal intervals, it would be well to say that I have found it convenient to construct a wedge-shaped piece of quartz, cut parallel to the axis of the crystal, and to use it along with two Nicol's prisms in such a manner that the spectrum may be divided into any requisite number of equal portions, by interference bands situated in any requisite position. This, of course, avoids the errors which so often happen when we compare together measurements that cannot be made with very great accuracy.

As an excellent illustration I select the coloring matter of Alkanet root (*Anchusa tinctoria*). It is insoluble in water, but is easily dissolved by alcohol, even when much diluted with water, and gives a clear pink solution. The spectrum is nearly the same when the color is dissolved in absolute alcohol, as when much water is present, only each of the absorption bands is situated rather higher. Thus taking the centres of the band, we have—

	b.	*c*.	*d*.
Absolute alcohol	4⅜	5⅞	7⅜
Very dilute alcohol	4¼	5¾	7¼

The general spectrum of the solution in dilute alcohol will be best understood from the following figure, No. 1:—

Fig. 3.



Acids produce no important change, and the effect of alkalies is best seen by gradually adding carbonate of soda. This alters the color to a more blue-purple, and the spectrum is changed in the manner shown in Fig. 3. The three bands seen in the neutral solution may be referred to as *b*, *c* and *d*, and their centres occur at equal intervals of about 1½. When enough carbonate of soda has been added to make it slightly purple, a fourth band, *a*, makes its appearance, separated from *b* by the same equal interval of 1½, whilst the other bands remain in the same position as at first, only modified in intensity. The band *a* becomes darker and darker as

more carbonate is added, until, when the solution is a fine purple, it is as dark as the others (see No. 2); and on adding more carbonate it becomes still darker, and the bands *c* and *a* more faint, until the solution is a purple-blue; and the spectrum has only the two well-marked bands *a* and *b*, shown by No. 3.

The bright blue coloring matter of the flowers *Lobelia speciosa* gives, when *neutral*, almost exactly the same spectrum as that of Alkanet root when *alkaline*, No. 3, having two well-marked absorption bands, whose centres are at $2\frac{3}{4}$ and $4\frac{1}{4}$; and on adding carbonate of soda, the upper one is gradually removed, and the centre of the lower is depressed to near $2\frac{1}{2}$. More or less similar results occur in the case of many other blue coloring matters; and on adding a slight excess of acid the general absorption is raised, and other bands may be developed higher up, at equal intervals; but when a large excess has been added, they are lost in a strong general absorption. Too strong an alkali may also destroy narrow bands in a similar manner, as is well seen in the case of Brazil wood. The neutral aqueous solution shows an absorption band, made far more distinct by the addition of bicarbonate of ammonia, which makes it pink and very fluorescent. The spectrum is then

$$4\tfrac{3}{4}\overset{*}{—}5\tfrac{3}{4} \ldots\ldots 7;$$

but on adding excess of ammonia the solution ceases to be fluorescent, the narrow absorption band is lost, and the spectrum becomes

$$3\tfrac{1}{2} \ldots 4\tfrac{1}{4}—8 \ldots 9\tfrac{1}{2}.$$

Ammonia does not produce this effect when the color is dissolved in alcohol, the solution remaining fluorescent and still giving the narrow band; and, as a general rule, that solvent greatly impedes or entirely prevents such changes, and on this account almost invariably shows absorption bands to the greatest advantage.

We therefore see from the above examples that the absorption follows the general rule, and is raised by acids, and depressed by alkalies; but this only applies to the absorption when viewed as a *whole*, and not the separate bands; for those reagents change their *intensity*, but not their *position*. In some cases, indeed, their position is slightly altered, so that perhaps it would be more correct to say that acids and alkalies may raise and depress the general absorption to an extent equal to a considerable fraction of its own great breadth; whereas they either do not change the position of narrow absorption bands, or merely raise and depress them by a fraction of their own narrow width. It is their very definite position that makes them so useful in this method of analysis.

Unfortunately, I have not hitherto been able to find a sufficient number of coloring matters giving rise to three or more well-marked absorption bands, to warrant a general conclusion; and therefore it is perhaps premature to conclude that their centres always occur at *equal intervals*. At the same time it is certainly a very common fact. When the maximum point of transparency occurs

between the different bands, there may be, as it were, a double interval; but then, sometimes, even this missing band may be seen under favorable conditions. A difference in the general absorption may also somewhat alter the apparent position of a band, if it is strongly shaded on one side, and not on the other; and the presence of impurities may also modify the results, so that absolute accuracy cannot be expected in all cases; and occasionally very narrow bands occur which appear to belong to a second system. It must be borne in mind that the bands are equidistant, only when measured by means of the interference spectrum. Thus, in the case of Alkanet root, when measured with a micrometer, instead of the intervals *a* to *b* and *c* to *d* being equal, they are related to one another about as $1\frac{1}{2}$ and 2, and thus the general law is entirely obscured. If subsequent research should prove that the bands are normally at equal intervals, it will be a fact of great value in deciding whether certain spectra are or are not due to a *mixture of colors;* since, if a band occurred at a perfectly unequal interval, it would show that there must be at least two substances. Even in the present state of our knowledge, any inequality should make us carefully search for some satisfactory reason for such a divergence from a common rule. My meaning will be better understood from the following examples.

If a little of the color of Brazil wood be added to the solution of Alkanet root, the bands are not altered, and are seen at $4\frac{1}{4}$, $5\frac{3}{4}$ and $7\frac{1}{4}$; but a little bicarbonate of ammonia developes a well-marked band, whose centre is at $5\frac{1}{4}$, and therefore at an interval of 1, instead of $1\frac{1}{2}$. The same is also well seen in the case of a mixed solution of Brazil wood and blue *Lobelia*. I therefore argue that if an unknown substance gave rise to similar spectra, with bands at unequal intervals, we ought strongly to suspect that it was either naturally composite, or that some new compound had been formed by decomposition. As a very good illustration, I may refer to the product of the action of acids on chlorophyll. The band in the red is not at an equal interval; but, on careful examination, it is seen to be made up of two bands, the upper of which is at an equal interval. I was not aware that these were due to two different substances, but was led to think it very probable; and Professor Stokes informs me that he has proved it to be the case. As an illustration of another kind of exception, I refer to the coloring matter of the pink Stock (*Matthiola annua*). The aqueous solution shows two bands, whose centres are at about $3\frac{5}{8}$ and $5\frac{1}{4}$; and on adding ammonia the upper is removed, and the lower depressed to $3\frac{1}{4}$. In spirit of wine they are at 4 and $5\frac{1}{2}$, and ammonia develops a third at 3, which are *not* equal intervals. However, if absolute alcohol be used, the bands are at $2\frac{3}{4}$, $4\frac{1}{8}$, and $5\frac{1}{2}$, which are *equal* intervals; and thus we see that the abnormal inequality is due to the presence of water, which causes the spectrum to be as if due to a mixture of two colors, when in reality it is the same color dissolved in two solvents.

(To be continued.)

EDUCATIONAL

THE MAGIC LANTERN

AS A

MEANS OF DEMONSTRATION.

(Continued from vol. liv., page 342.)

HAVING now discussed the various preliminary arrangements as to the manufacture and storage of gases, arrangement of jets, of lanterns, and of lenses, we will proceed to describe the various experiments which may be performed with the instrument under consideration.

In the first place, if the lantern is to be used not simply for the exhibition of pictures, but, as we assume in this discussion, for the general demonstration of optical, chemical, electrical and other phenomena, the objective lens or lenses should be supported, not by a continuous tube from the condensers, but by a separate stand, as shown roughly in Fig. 10, vol. liv., page 132, leaving an open space between condensers and objective. A large disk or diaphragm attached to the stand or cell holding the objective, will prevent any scattered rays from reaching the screen under any circumstances. Should a prism, or other body reflecting light strongly, be interposed, a little tube of stiff paper, blackened within, may be readily arranged and attached to some portion of the apparatus. This, however, is seldom needed.

A little table or bench placed in front of the condensers, and rising as high as their lower edge, with several slips of wood or blocks of various thickness, will furnish convenient support to the objects employed. Among these, we shall first describe

Tanks, with their various Forms and Applications.

The tank for a magic lantern, which we have found in all respects most convenient and efficient, is constructed as follows:—

Four simple screw-clamps, such as are shown in the following figures, each capable of embracing an object three-quarter inch thick, are provided two plates of glass, either plate or flat sheet, three and a half by four and a half inches, and a square strip of sheet rubber eleven inches long, and a half inch in each of its other dimensions. This is easily obtained from the thick sheets, manufactured and sold for pump and other packings. Notches are cut in the rubber at the proper points, it is bent to form three sides of a rectangle, placed between the glasses, and the whole firmly secured by means of the clamps. With a simple tank of this description, a great number of very beautiful and instructive experiments may be performed.

Thus, to illustrate the effect of refraction upon light, the tank may be nearly filled with water and some highly refracting solution, or liquid, such as muriate of tin of the shops (solution of protochloride of tin with excess of hydrochloric acid), alcohol, or even salt water poured in from a pipette. For this and many other purposes, it will be found extremely convenient to attach to the upper end of the pipette, one of the elipsoidal rubber balls, now easily obtained, when, by manipulation of this, a liquid may be drawn into or expelled from the pipette, with great convenience and promptitude.

In the experiment above described, the appearance upon the screen while the refracting liquid is being introduced, is that of a submarine volcano, belching forth vast clouds of black smoke and lava, which are, however, rapidly dissolved in the surrounding ocean. When the density of the liquid has been changed in a marked degree, a similar effect may be produced by a jet of fresh water.

In this and other cases, it is very desirable to use water deprived of air by previous boiling, as the formation of bubbles on the sides of the tank is thus prevented.

Again, a solution of cochineal in alcohol, introduced in a tank of water as above, exhibits on the screen a magnificent crimson fountain, shooting up twenty or thirty feet, curling over, and falling down in the most graceful curves and convolutions, while the dark outlines and shades which it develops, exhibit the same effect of refraction as before. A further illustration explanatory of the same property, may then be furnished, by introducing a small empty test-tube into the tank, and then allowing it slowly to fill with water from the same. The empty test-tube will be black on the screen, except a bright streak along the middle, but as fast as

it fills, will become clear and transparent. A similar action may be shown, as we have before mentioned, by placing a small wine-glass (or, with a large lantern, a goblet) as an object, and filling it with water. In this case the empty glass is clear, but becomes black when filled.

To illustrate chemical reactions, we introduce, for example, solution of litmus, covering the screen with a delicate blue sky. A few drops of weak acid being then introduced, and allowed to mingle slowly, gives us beautiful combinations and changing forms, of red and yellow clouds, as seen in a sunset sky.

Again we place in the tank of water a little sulphate of copper solution, and force into this weak ammonia from the pipette. We have then upon the screen an impressive display of rolling and surging clouds, first accumulating to blackness, but then dissolving, as they sweep about, into a serene blue. Dilute sulphuric acid affects like changes in an inverse order, and a few drops of ferrocyanide of potassium then develops a red-brown precipitate in huge curdled masses, which look as though they might weigh tons.

In fact, these experiments, which, as all can see, may be modified without limit, add to their intrinsic beauty a new element, grandeur, from the seeming hugeness and overwhelming quantity of the materials employed, as shown upon the screen. Solutions by tons, precipitates by the cart-load, even though seen but in images, convey a strong and peculiar impression to the mind.

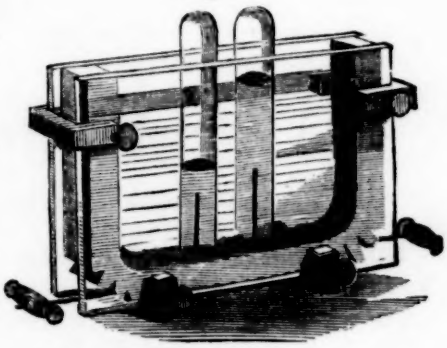
When a number of such experiments are to be exhibited in succession, a great improvement may be effected as regards convenience and rapidity of manipulation, by arranging the tank as follows:—With a wet cork-borer, three holes are made in the rubber strip, one at either side near the upper edge of the tank, and one beneath at the lowest part; short glass tubes are inserted in each of these, and by means of rubber hose are connected as follows:—One of the upper openings, with a bottle or jar of water placed on a shelf above, and provided with a stop-cock or nipper-clip; this serves to introduce fresh water. The other upper and the lower opening, by means of a T connection, communicate with an escape-pipe leading to a bucket or like receptacle. Close to the lower opening is placed a nipper-clip; the upper one, or overflow, is never closed. When one experiment has been performed, we press the clip of the outlet, when the contents of the tank escape, producing on the screen the appearance

of a curtain rolling up. The clip or stop-cock from the supplying vessel being then opened, the tank is filled, and a fresh curtain of clear water rolls down upon the screen.

To illustrate the change in color produced by chemical reaction, we may introduce one of two reagents, *e. g.* pernitrate of iron, in the tank, and the other, *e. g.* sulphocyanide of potassium, in a test-tube. Two liquids are thus seen in apparent contact, but without reaction until the tube is inverted, when the liquids mingle and produce the well-known crimson coloration. The solution of zinc in dilute sulphuric acid, develops another of the pleasing effects which may be shown with this simple apparatus.

Passing now to the department of electricity, we may again display the galvanic decomposition of water, with a tank arranged as in Fig. 17. Though for the best effect, we here require to correct the inversion of the image, and this may be best accomplished by one of Mr. Zentmayer's prisms, fully described in this Journal (vol. liii., page 406). In this tank, two stout copper wires, with strips of platinum soldered to them, are thrust through the bottom of the tank, and connected with the battery by binding screws outside. Small test-tubes are then filled with water, and may be inverted in the air without the water running out, and may therefore be easily placed over the platinum strips in the tank. With a moderate battery (five or six Bunsen elements), we see upon the screen the liberated gases, in bubbles of perhaps ten gallons each, collecting in reservoirs whose capacity could be best expressed in hogsheads. Other electric changes of decomposition may be in like manner exhibited in U tubes emersed in tanks, or in tanks provided with porous or perforated partitions. So again a small electro-magnet, lifting filings, tacks, or beads, and dropping them again, may be exhibited most clearly.

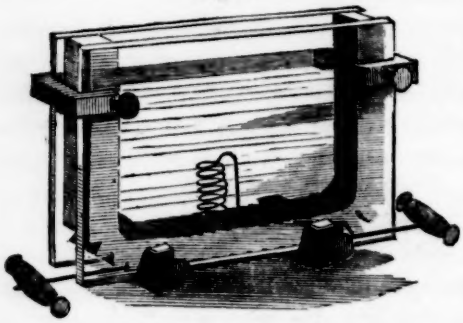
Fig. 17.



Another fact in physics which it is impossible to show to a large audience, is the convection of heat by liquids, and this the lantern

tank demonstrates most clearly. We arrange a tank as in Fig. 18, with a coil of platinum wire, which may be heated in a moment by connection with the battery. The tank is filled with water, a little aqueous solution of cochineal being introduced at the bottom; it is then placed in the lantern, and its image, erected by the prism, is projected on the screen. We connect with the battery, and at once a crimson column of the heated liquid rises from the wire helix (which looks like a steam coil), and rolls over in graceful curls at either side.

Fig. 18.



(To be continued.)

Franklin Institute.

Proceedings of the Stated Monthly Meeting, November 20th, 1867.

THE meeting was called to order with the President, Mr. J. V. Merrick, in the chair.

The minutes of the last meeting were read and approved.

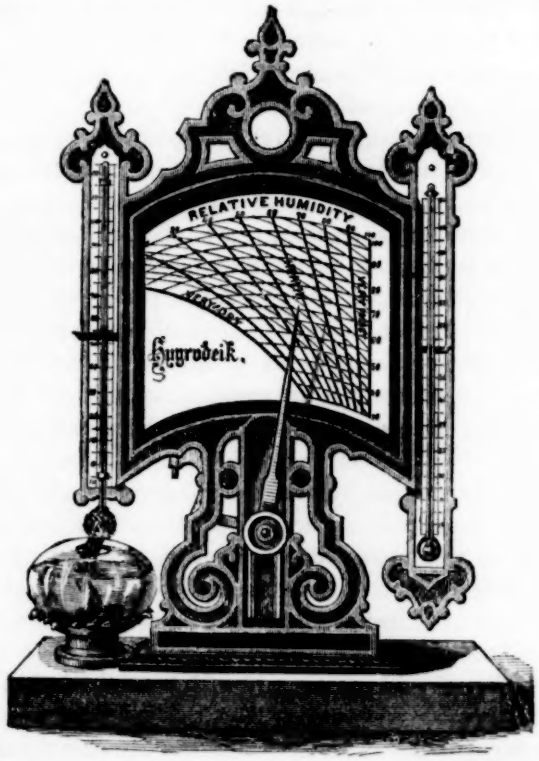
The Actuary submitted the minutes of the Board of Managers, and reported that at their stated meeting held November 13th, inst., a letter was received from the Secretary of the Royal Institution of London, at the request, on the part of the family of Professor Faraday, to communicate to the Secretary of the Franklin Institute the death of the Professor on the 25th of August, in the 77th year of his age.

On motion, a committee was appointed to prepare suitable resolutions in relation to Professor Faraday.

Donations were received from the Royal Astronomical Society, Chemical Society, and the Statistical Society of London, and the Association for the Prevention of Steam-Boiler Explosions, Manchester, England; the Literary and Historical Society, Quebec, Canada; the Hon. William D. Kelley, member of Congress, Washington, D. C.; Professor Albert R. Leeds and James D. McIntyre, Philadelphia.

The various Standing Committees reported their minutes, and the Committee on Experiments in Steam Expansion reported progress.

The report of the Resident Secretary, on Novelties in Science and the Mechanic Arts, was then read, after which Mr. Robert Briggs described, with diagrams projected on the screen, as is usual at the meetings of the Institute, Edson's Hygrodeik, or instrument for showing at a glance the amount of moisture contained in the air.



One of these instruments shown in the accompanying cut, was also exhibited. They are manufactured by N. M. Lowe, No. 103 Court street, Boston, whose connection with the apparatus is thus expressed by the inventor: "Mr. N. M. Lowe, the manufacturer of the instrument, and to whom the credit of the beautiful mechanical details and finish is due, is now designing a barometer of such a nature that it may be combined with the hygrodeik."

The description of this apparatus given by Mr. Briggs is as follows:

The instrument is the usual arrangement of a wet and dry bulb

thermometer upon a stand, as shown in the accompanying illustration. Between the two thermometers is placed a scale and pointer, the extremity of which, when it has been moved so as to bring the sliding marks on the two thermometers to correspond to the heights of mercury they indicate, will show at one view the per centage of moisture present as compared to total saturation, the grains of water to each cubic foot of air, and the tension of vapor in inches of mercury. Any person who has had occasion to calculate any of these physical data from the psychrometer (or wet bulb thermometer) by the aid of tables, will appreciate the relief which this instantaneous solution of the problem affords.

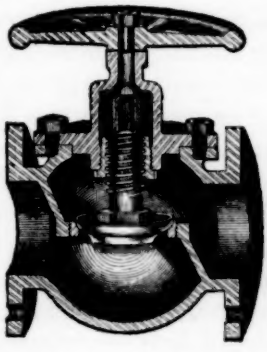
With the same precautions as to exposure of the two thermometers to protect them from external influences of radiation, imperfect contact with the air, and especially an observance of the precautions needed for the wet bulbs, that the water should be free from salts, the wick clean, and the bulb fanned to remove its own little atmosphere of vapor when taking an observation; it is perfectly possible to so form the scale that its indications shall be as accurate as calculation. The construction of the indicating part is very simple. At the back of the instrument is an upright bar in line with the thermometers, which carries a slide to which the pointer is attached. To this slide is fixed a rigid arm, which carries the mark on the dry thermometer side, so that by raising or depressing the slide by the knob in front, the mark is placed opposite the surface of the mercury column on that side. The pointer is attached to this knob as a centre of movement. Behind the slide, on the axis of the knob, is an arm about one-third as long as the pointer, which elevates and depresses the mark on the wet bulb side.

By examining the illustration, it will be noticed that when the mark on the dry side is at any degree, the end of the pointer will, if it is swung across the scale, follow the circular path or line of degrees corresponding, and, as has been described, swinging this pointer elevates or depresses the mark on the wet side, the end of the pointer showing by the divisions across the circular lines the per centages of humidity. The diagonal cross lines crossing both the temperature and the per centage lines, give similarly the grains of vapor per cubic foot of air, and the tension of vapor in inches of column of mercury.

In describing this instrument, Mr. Briggs took occasion to remark, that, aside from its value as a meteorological instrument of observa-

tion and its application to some hygrometric purposes connected with manufacturing operations, such as paper-making, fine muslin or lace-working, drying of delicate materials, &c., it was peculiarly valuable and satisfactory at this time, in forming a ready and perceptible way for overthrowing some current fallacies as to moisture for hygienic demands.

He said that the great cause of the unhealthfulness of our climate, as of all temperate climates, lies in the varying condition of atmosphere as to moisture. That with our colder northerly and northwesterly winds, the external air had an extreme low dew point, and while it was possible to warm the air when such winds prevail to the comfortable temperature of 70° to 80° (the English maximum comfortable temperature being 62°), it was neither practicable nor desirable to impart to it any addition of moisture. Any such addition as should give a summer dew point, would involve an expenditure of fuel two-thirds as great as that of heating the air, and an evaporation of quantities of water far beyond any pan contrivances ever devised, requiring regular steam-boilers to be attached to each house furnace. More than this, the effect on the lungs in changing from the summer air within doors, to the winter one without, would aggravate all the derangements from difference of temperatures solely, in the most serious manner. In fact, this instrument would lead physicians and observers to the knowledge of the fact that the presence of any considerable quantity of moisture beyond that existing out of doors, at the same time of moisture in a habitable room, was a sure indication of its want of ventilation and its insalubrious condition.

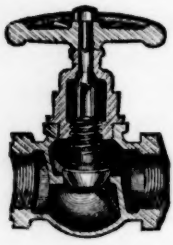


Shaffer's patent self-packing valve was then exhibited in model and by sectional diagram, and its construction and purpose described. The accompanying illustrations show the internal arrangement and the method by which it is proposed to dispense with a stuffing-box or gland about the stem of the valve.

The general form is that of the ordinary globe-valve, of the most approved construction, made either entirely from brass or with iron bodies and centre-piece or cap, and brass valve, valve-stem, nut, and seat.

The valve-stem proper, to which the wheel or handle is attached, has a conical enlargement, which is brought, by a nut on the top of the wheel, to bear upon a seat formed within the valve on the centre-piece, making a steam-tight joint.

Below this enlargement the stem has the form of a key, two nearly semicircular grooves being cut in it lengthways. This key end is inserted, loosely, into a socket formed in the end of the screw, which opens or closes the valve. The screw runs in a nut, which is either made in or affixed to the centre-piece of the valve: to this screw is attached, by collar and nut, the disk of the valve, the disk being free to rotate upon the lower end of the screw.



It has been before proposed to make self-packing valves similar to this, except in one respect; all former plans putting the screw upon the valve-stem, and running into a nut within a key attachment to the disk, the key guiding itself in a socket made in or affixed to the centre-piece.

The effect of such an arrangement is, that the pressure of seating the valve is expended upon the seat about the stem, and the twisting movement quickly wears it so that it ceases to be steam-tight. Besides, in such case, when the valve is seated, the screw, unless it is perfectly in line with the stem, strains its seat by the sideways pressure, and leaks. The construction patented obviates both these defects, and has been found by the past year's use to move easily, and to keep in perfect condition under continued service. The key is made in the shape shown, in preference to square or any other form, to prevent its binding in the socket when turned, as the surface of contact at such time is normal to (square with) the motion imparted. It was stated that 5000 or 6000 of these valves are now in use.

After this Mr. Vanderburgh gave a description of the new process for the manufacture of artificial stone, by mingling sand and dry lime under influence of high pressure steam. (A full description of this process is promised for a future occasion.)

Prof. R. E. Rogers made some remarks on the importance of potash in all reactions developing artificial silicates.

Some questions were asked by other members, and replies given by Mr. Vanderburgh, after which the meeting, on motion, adjourned.

HENRY MORTON, *Secretary.*

A COMPARISON *of some of the Meteorological Phenomena of* NOVEMBER, 1867, *with those of* NOVEMBER, 1866, *and of the same month for* SEVENTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 11¼′ W. from Greenwich. By PROFESSOR J. A. KIRKPATRICK, of the Central High School.

	November, 1867.	November, 1866.	November, for 17 years.
Thermometer—Highest—degree.....	69·00°	70·00	80·00
" date.....	9th.	29th.	1st, '60.
Warmest day—mean ..	62·33	64·50	72·30
" " date.....	9th.	29th.	9th, '57.
Lowest—degree.....	24·00	29·00	16·00
" date.....	19th.	26th.	25th, '60.
Coldest day—mean	31·00	35·83	23·30
" " date	18th & 19th.	24th.	25th, '60.
Mean daily oscillation...	14·47	13·63	13·26
" " range.....	6·37	5·85	5·70
Means at 7 A. M.	42·93	42·95	41·40
" 2 P. M.	51·33	52·33	50·43
" 9 P. M.	46·68	46·93	44·69
" for the month....	46·98	47·40	45·51
Barometer—Highest—inches.....	30·342	30·358	30·661
" date.....	5th.	5th.	12th, '51.
Greatest mean daily pressure	30·325	30·327	30·520
" " " " date...	5th.	5th.	12th, '51.
Lowest—inches	29·250	29·327	29·080
" date.....	29th.	16th.	4th, '64.
Least mean daily pressure...	29·593	29·382	29·150
" " " date...	29th.	16th.	4th, '64.
Mean daily range.....	0·182	0·157	0·182
Means at 7 A. M	30·006	29·913	29·915
" 2 P. M	29·972	29·858	29·870
" 9 P. M	29·994	29·891	29·902
" for the month.....	29·991	29·887	29·896
Force of Vapor—Greatest—inches	0·548	0·513	0·832
" date	10th.	29th.	8th, '57.
Least—inches.....	·100	·060	·055
" date.....	18th.	25th.	25th, '57.
Means at 7 A. M.....	·236	·218	·224
" 2 P. M.....	·256	·213	·229
" 9 P. M.....	·258	·242	·234
" for the month...	·250	·224	·229
Relative Humidity—Greatest—per cent	94·0	89·0	100·0
" date.....	10th.	11th & 26th.	Often.
Least—per cent....	41·0	25·0	25·0
" date.....	16th.	25th.	7,'63 & 25,'66
Means at 7 A. M....	80·3	74·6	77·2
" 2 P. M....	63·0	51·0	58·8
" 9 P. M....	76·5	71·0	73·3
" for the month	73·3	65·5	69·8
Clouds—Number of clear days*.....	8·	10·	8·5
" cloudy days	22·	20·	21·5
Means of sky covered at 7 A. M	65·0 per ct	56·7 per ct	60·6 per ct
" " " 2 P. M	66·0	56·7	60·6
" " " 9 P. M	50·0	49·0	51·8
" " for the month	60·3	54·1	57·7
Rain—Amount—inches.....	2·540	1·474	3·559
No. of days on which rain fell..... ...	10.	7·	10·1
Prevailing Winds—Times in 1000.....	s76°32′w·261	s84°17′w·251	s74°47′w·255

* Sky one-third or less covered at the hours of observation.